Karst and Caves of Great Britain

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Chapter 5

The Mendip Hills karst

INTRODUCTION

The Mendip Hills rise east of the Bristol Channel as an elongate plateau roughly 30 km long and 8 km wide, composed largely, but not entirely, of cavernous limestone (Figure 5.1). At their western end they stand 200 m above the Somerset Levels, but their eastern end declines gently and is buried beneath the Jurassic scarplands.

The carbonate succession includes almost the entire Dinantian sequence of the Lower Carboniferous, and reaches over 800 m in thickness. The main karstic rocks are the strong, fine-grained shelf limestones; they include beds of very fine-grained calcite mudstone, known as chinastone, and also beds which are conspicuously bioclastic or oolitic. Some of the carbonates are dolomitized and there are many thin clastic horizons within the main sequence. The lowest unit in the succession is the Black Rock Limestone, a dark well bedded series in which most of the swallet caves are formed. Above this, the Burrington Oolite, Clifton Down Limestone and Hotwells Limestone are all pale grey but weather to the white patina seen at outcrop, notably in the white cliffs of Cheddar Gorge.

The limestone is underlain by Dinantian calcareous shales with thin interbedded limestones; these are known as the Lower Limestone Shales and are transitional from the Devonian Old Red Sandstone. The sandstones crop out in four anticlinal cores to form hills rising 30–60 m above the limestone plateau (Figure 5.1). On the flanks of the Mendip plateau, the limestones are overlain unconformably by Triassic screes and fan deposits, formed largely of limestone blocks and known locally as the Dolomitic Conglomerate: these are also cavernous at some locations, notably at Wookey Hole, where they constitute an integral component of the single karst aquifer. On the lower, eastern part of the plateau, outliers of Mercia Mudstone, silicified limestones of the Harptree Beds and Liassic limestone lie unconformably on the Carboniferous limestone. Triassic palaeokarst was restricted by the contemporary desert environment, and most of the cave infills

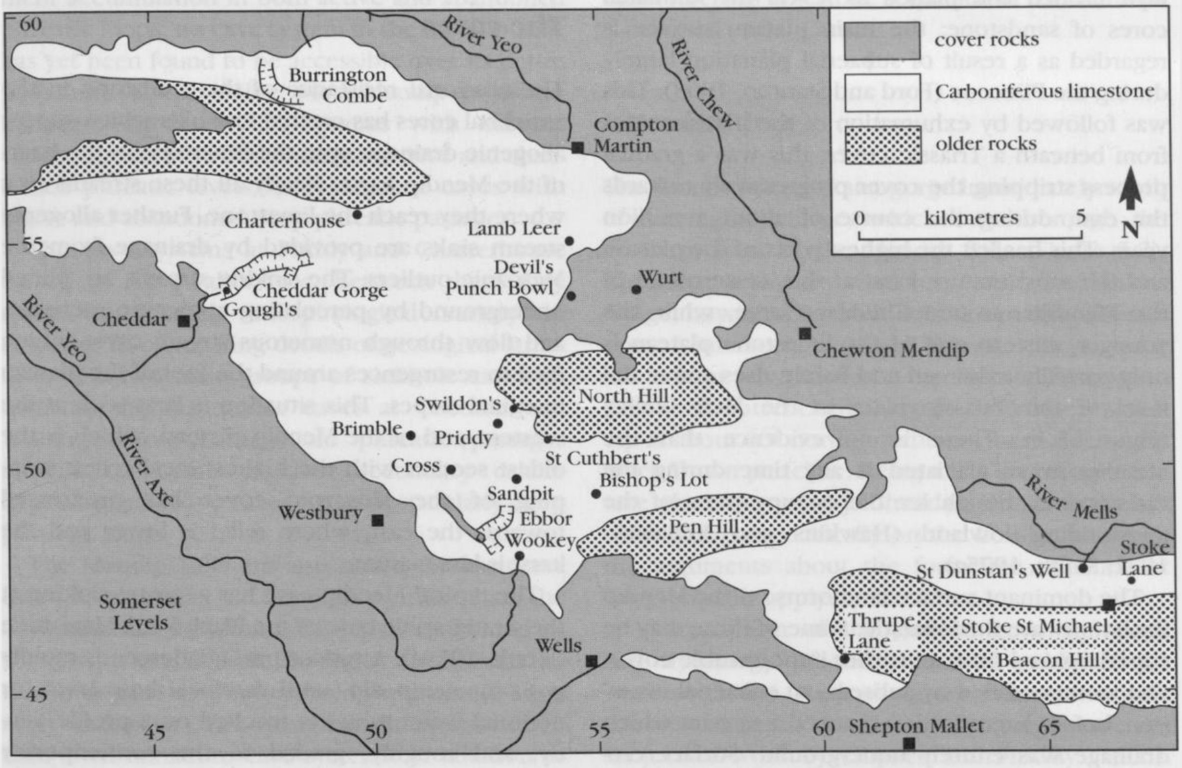

Figure 5.1 Outline map of the Mendip Hills karst, with locations referred to in the text. Cover rocks are mostly the Triassic and Jurassic mudstones and limestones; Upper Carboniferous rocks form the thrusted outlier on the east side of Ebbor Gorge. The Triassic Dolomitic Conglomerate is included with the Carboniferous limestone where it is composed of blocks of the limestone and is an integral part of the karst. Older rocks are the Devonian Old Red Sandstone and the Dinantian Lower Limestone Shale.

appear to be in tectonic fissures and associated with Jurassic neptunian dykes (Ford, 1984; Stanton, 1991).

Structurally the Mendip Hills are the most complex of Britain's four major regions of cavernous karst. They are essentially formed of four *en-echelon*, periclinal anticlines. Marginal dips are mostly between 20° and 70°; they are steepest and at some locations overturned on the northern limbs. Extensive faulting, overthrusting and overfolding complicates the geology (Smith, 1975a). In some areas, the limestone contains hydrothermal mineralization, but this has not influenced the karst processes in the way that it has in the Peak District.

The karst

The Mendip Hills form an upland exhumed from beneath a Mesozoic cover, and traces of Triassic features survive, mainly in the marginal slopes. Though the limestone hills may have been stratimorphic early in the Trias, the summit surface is now eroded and planed to reveal the anticlinal cores of sandstone; the main plateau surface is regarded as a result of subaerial planation largely during the Pliocene (Ford and Stanton, 1968). This was followed by exhumation of the plateau sides from beneath a Triassic cover; this was a gradual process stripping the cover progressively towards the east, during the course of about a million years. This has left the highest parts of the plateau and the most mature karst at the western end of the Mendips, around Cheddar Gorge, while the younger, eastern end of the limestone plateau is only partially exhumed and barely rises above the level of the Triassic plain in the Mells Valley (Figure 5.1). There is no evidence that the Mendips were glaciated at any time during the Pleistocene, though ice did occupy parts of the surrounding lowland (Hawkins and Kellaway, 1971; Smith, 1975a).

The dominant surface landforms on the Mendip limestones are fluviokarstic. Some of these may be superimposed from an earlier impermeable cover, and were modified by subsequent subaerial evolution, before karstification reached a stage at which drainage was entirely underground. Surface erosion was then temporarily re-established under periglacial conditions during the Pleistocene, when karstic drainage was hindered by the ground ice (Smith, 1977). Dry valleys are entrenched into much of the upland limestone surface, and these steepen into gorges in their descents of the plateau margins (Ford and Stanton, 1968); the best known is Cheddar Gorge, which has the largest feeder system of dry valleys.

On the interfluves and the plateau margins, the topography is more disorganized and less fluvial; large, shallow, closed depressions create some limited areas of polygonal karst. Solutional dolines of various morphologies and origins are scattered across the karst plateau, but many have been modified by past mining activities. Subsidence dolines are numerous in some outcrops of the Harptree Beds, but the absence of till precludes the development of extensive fields of subsidence dolines such as are found in Britain's glaciated karstlands. There are no limestone pavements. Rock scars are not a feature of the karst, except along the steeper flanks of the deeper sections of the gorges. Thick soils on the plateau have a significant loessic component, but are replaced by thin stoney soils on steeper slopes; except for the steeper valley and marginal slopes, the whole area is now farmland.

The caves

The erosional resistance of the sandstone in the anticlinal cores has created low hills which supply allogenic drainage onto the limestone in the heart of the Mendip karst. Nearly all these streams sink where they reach the limestone. Further allogenic stream sinks are provided by drainage from the Mesozoic outliers. The sinking streams are joined underground by percolating autogenic recharge, and flow through numerous stream caves which feed to resurgences around the foot of the plateau marginal slopes. This situation is best seen at the western end of the Mendip plateau, which is the oldest section with the highest local relief; stripping of the Mesozoic cover has progressed towards the east, where relief is lower and the karst is less mature.

The typical Mendip cave has a stream sinking at the stratigraphic base of the Black Rock Limestone (Smith, 1975a). A vadose passage descends rapidly with the steep dip, until the local base level (or notional water table) is reached on a profile gently, and roughly, graded to the contemporary resurgence level. From there, a phreatic cave continues with a looping profile following down the bedding planes and up the joints, with sections of shallow, sub-horizontal loops along the strike. Continued erosion within the looping phreatic passages cuts trenches through the loop crests and raises the loop troughs by sedimentation and paragenetic roof solution; together these processes lead to a more uniformly graded passage profile. The Mendip Hills have long been cited as the type area of cave development in steeply dipping limestones (Ford 1968; Ford and Ewers, 1978).

Long-term base-level lowering and episodic rejuvenation fossilize the phreatic systems, commonly before they have achieved graded profiles above their contemporary risings. Major rejuvenations are generally followed by utilization of completely new phreatic routes at lower level, but inception and initiation of the lower routes had already been started deep within the earlier phreas. Though the geological controls on cave development are strong, the inclined networks of intersecting fractures in the limestone permit rapid responses to rejuvenation, and there is a minimum of widespread water table perching within the modern aquifer.

Due to passage constrictions within the phreas, the depth of the active phreatic loops, and sediment accumulation in both active and abandoned phreatic loops, no cave system in the Mendip Hills has yet been found to be accessible over its entire path from sink to rising. Most Mendip caves are therefore either swallet systems with influent vadose streamways descending to active and abandoned phreatic levels, or resurgence caves with active and abandoned deep phreatic passages.

The cave systems at Priddy and Charterhouse are all of the swallet type. Between them they show considerable morphological variety in response to contrasting details of geological structure. The two main groups of sinkhole caves all drain to the resurgence caves at Cheddar and Wookey; these contain old phreatic passages notable for some of their secondary calcite deposits, and active caves with spectacularly deep phreatic loops.

The Mendip Hills are also noted for karst and cave development in lithologies other than the Carboniferous limestone. Of the caves formed by solution in the Triassic Dolomitic Conglomerate, the outer parts of Wookey Hole are the largest and most extensive. The Mesozoic limestones have their own miniature cave systems, in addition to the piping failures and collapse stoping induced by drainage into the underlying Carboniferous.

The absence of glacial cover enjoyed by the Mendip karst throughout the Pleistocene permitted a very complete record of sediments to accumulate in the caves. These sequences of both clastic detritus and calcite flowstone are exceptionally valuable to Pleistocene stratigraphy (Atkinson *et al.*, 1978, 1986); correlations with surface evolution are facilitated by their survival in the successions of rejuvenated phreatic cave passages which evolved in close accord with falling resurgence levels.

BURRINGTON COMBE

Highlights

Burrington Combe is a fine example of a fluvial karst gorge, which was cut largely under periglacial conditions across the narrow steeply dipping limestone outcrop on the northern side of the Mendips. Relict and active caves exposed in the limestone flanks provide evidence of a long history of solutional erosion predating the formation of the valley. The lower part of the gorge has exposed part of an infilled Triassic gorge or wadi. An almost complete succession through the Carboniferous limestone sequence of the Mendips is exposed in the Combe.

Introduction

The Combe is a dry karst gorge immediately south of Burrington village, which cuts thorough the northern flank of the Mendip Hills (Figure 5.2). The gorge is in many ways very similar to Cheddar Gorge; however, its walls contain smaller cliff sections, it intersects two fossil Triassic valleys, and it has a large alluvial fan at its mouth. Burrington Combe is entrenched through limestones which dip at about 60° north, on the northern side of the Black Down pericline. Being a less spectacular feature than the nearby Cheddar Gorge, little has been written specifically on the Combe, although the arguments about the formation of Cheddar Gorge equally apply.

A description of the general geomorphology and hydrology of the area was published by Tratman (1963), while the gravels associated with the alluvial fan at the foot of the gorge were the subject of work by Clayden and Findlay (1960). The geological succession exposed in the Combe is described in detail by Green and Welch (1965). Many caves occur in the side of the Combe, documented by Barrington and Stanton (1977) and by Irwin and Jarratt (1992). Although most are very

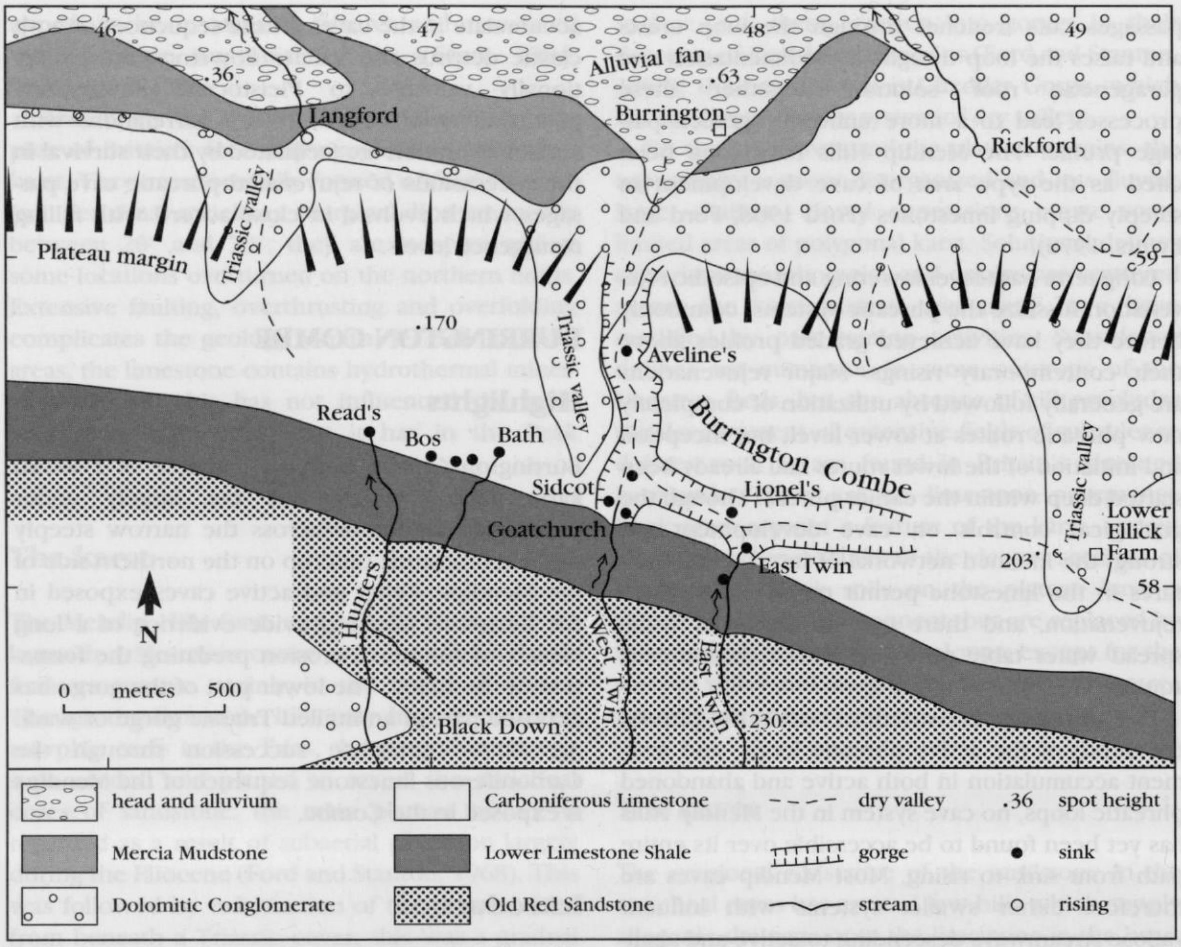

Figure 5.2 Geological map of Burrington Combe and the infilled Triassic valleys cut into the northern slope of the Mendip Hills (after Williams and Farrant, 1992).

small, they provide evidence of former stages in the evolution of the gorge.

Description

The upper part of the gorge is developed along the strike of the Black Rock Limestone, before turning sharply north and cutting through the rest of the Carboniferous limestone sequence. Burrington Combe partially intersects two infilled fossil Triassic valleys, which can be recognized by the outcrops of Triassic Dolomitic Conglomerate which infill them. One is located near the head of the combe at Lower Ellick Farm, while the second is exposed where the combe beaches its eastern flank near its lower end (Figure 5.2).

The combe is a steeply graded feature, descending from 200 m at Lower Ellick Farm to debouch at around 80 m onto the lowland excavated in Mercia Mudstone to the north. A well developed alluvial fan (marked as head on most geological maps) is developed at the foot of the gorge and spreads out into the Vale of Wrington to the north. Two tributary valleys, the East and West Twin valleys, descend steeply off Blackdown's northern slopes to join the main combe about halfway down. The upper parts of these tributary valleys are developed on the Old Red Sandstone and have surface streams which disappear underground at the contact with the Carboniferous limestone, with some small sinks in the East Twin into the Lower Limestone Shales. Solutional voids in the Shale group are also revealed in a drainage adit driven through them from the floor of the West Twin valley. The combe is dry, except in extreme floods, including that of 1968 which cut a trench through the clastic fill in the East Twin valley (Hanwell and Newson, 1970); normal drainage is now underground, and resurges at the Rickford and Langford Risings (Newson, 1972; Crabtree, 1979), east and west of the mouth of the combe (Figure 5.2).

Many caves have been exposed by the downcutting of the combe, of which the most extensive are the inclined mazes of Goatchurch Cavern and Lionel's Hole (Figure 5.2). These are mainly abandoned phreatic systems, and thus predate valley incision; they represent fragments of earlier generations of swallet caves and the complex phreatic networks which they fed (Bull and Carpenter, 1978). A newer generation of small sinks has developed in the valley floor. Aveline's Hole, located near the foot of the combe is the remains of a major phreatic tube, which was once part of a resurgence cave, but now acts as a sink for road drainage. Another set of abandoned and active stream sinks is located on the hillslope west of the combe. From east to west these are Bath Swallet, Rod's Pot, Drunkards Hole, Bos Swallet and Read's Cavern, forming a series of steeply descending caves developed downdip; they are almost certainly linked, although no connections have been found yet (Williams and Farrant, 1992). Their descending, dip-orientated passages contrast with the level strike-oriented rifts in Lionel's Hole, Goatchurch Cavern and the other caves at lower levels in the combe.

Interpretation

Burrington combe clearly shows the features associated with fluvial erosion during periglacial periods, and as such is very similar to Cheddar Gorge. However, the smaller catchment and the more limited relief has created a less dramatic gorge than that at Cheddar. This has meant that cavern collapse has not so commonly been invoked to explain its development. Both Reynolds (1927) and Tratman (1963) recognized the fluvial origin of the combe. Tratman went further and suggested the valley was eroded during periods of periglacial spring snowmelt, when the ground was frozen and underground drainage impeded. The large alluvial fan below the mouth of the gorge consists largely of gravel, produced by intense frost action and transported by periodic torrents of water flowing down the combe (Clayden and Findlay, 1960; Findlay, 1965; Stanton, 1977). The relationship between the Combe and the alluvial fan is clearer here than at any other site on Mendip. Deposition of the fan may also have been responsible for diverting karstic drainage to the two modern Risings on either side of it (Figure 5.2), in a style reflecting the diversion of surface streams off the crest of an aggrading fan. Although much of the combe was excavated under periglacial conditions, its early stages may have pre-dated significant karstification, and could have been cut by normal surface drainage.

The caves exposed in the side of the gorge provide evidence of underground solutional erosion which pre-dates the surface excavation of much of the gorge. The modern active cave system appears to be fairly immature. This is shown by the bifurcation of the drainage to two separate springs and the small nature of the active streamways. As yet no dating studies have been completed, but an absolute chronology for the caves would provide a time-scale for the geomorphological evolution of the combe.

It has been suggested that many of the modern valleys on Mendip follow earlier infilled Triassic valleys (Ford and Stanton, 1968). This is not the case in Burrington. The combe truncates the head of one such valley at Lower Ellick farm (Figure 5.2), but does not follow it. Similarly, the combe intersects another Triassic valley near the foot of the modern gorge, but, instead of following it, runs parallel to its eastern flank, cutting partly into the Carboniferous limestone. The Pleistocene erosion of the combe is independent of earlier Triassic development, and the Dolomitic Conglomerate does not appear to have offered a line of least resistance.

Conclusions

Burrington Combe is an excellent example of a fluvially eroded valley cutting through steeply dipping limestone, and has a long history of development through the Pleistocene. It partially intersects two earlier infilled Triassic valleys, but unlike many other valleys on Mendip, is not directly influenced by them. Ancient caves which have been truncated by downcutting of the combe provide evidence of a long history of solutional development. The combe also provides an excellent exposure of virtually the entire Carboniferous limestone sequence.

CHARTERHOUSE CAVES

Highlights

The Charterhouse caves encompass classic examples of vadose swallet caves in steeply dipping limestones. Their varied and complex morphologies, and extensive sediment and speleothem deposits, provide a valuable record of the Pleistocene development of the Mendip plateau and adjacent lowlands. These caves have been, and continue to be, the scene of intensive scientific research, often pioneering new techniques and methodologies. As a basis for so much karst research they are of international importance.

Introduction

Close to the centre of the Mendip limestone plateau, a group of ten caves lies along the southern flank of Black Down, 3 km north-east of Cheddar (Figures 5.1 and 5.8). Four of these are major influent cave systems, fed by allogenic streams draining south from the Old Red Sandstone outcrop of the Black Down pericline. The sinks are all close to the base of the Black Rock Limestone, and the known cave passages are in the lower beds of this unit, which dips to the south at 15–30°. The limestone is fractured by a number of faults, which may be associated with local steepening of the dip and have brecciated zones up to 6 m wide; it is also well jointed, with the dominant set having a roughly north–south trend. All the water from the caves resurges at Cheddar Rising, at the foot of the gorge.

The Charterhouse caves have been intensively studied, partly as a consequence of their proximity to the very active karst research unit in Bristol University. Detailed accounts of the main caves have been published by Goddard (1944), Stride, R.D. and Stride, A.H. (1946, 1949), Atkinson (1967), Atkinson *et al.* (1986), Ford (1964), Norton (1966), Smart and Stanton (1974) and Smart *et al.* (1984). Descriptions of the caves can be found in Barrington and Stanton (1977) and Irwin and Jarratt (1992). Further accounts of the geomorphology and development of the systems are given in Drew (1975b), Donovan (1969) and Ford (1965b, 1968). Aspects of the hydrology have been investigated by Atkinson (1968b), Atkinson *et al.* (1967), Drew (1975a), Stenner (1973), Smart and Hodge (1979, 1980), Smith and Mead (1962), Stanton and Smart (1981), Friederich (1981) and Friederich and Smart (1981, 1982). Effects above and below ground of the major floods in July 1968 were described by Hanwell and Newson (1969, 1970), Newson (1969) and Savage (1969). Uranium-series dates for some of the sites have been published by Atkinson *et al.* (1978, 1984); others remain unpublished, while dates derived from uranium-series decay and electron spin resonance, and studies of sediment remnant magnetism are recorded by Farrant (1995).

Description

The most westerly cave in the group is Tyning's Barrows Swallet (Figure 5.8). The cave consists of an initial series of narrow vadose passages descending steeply downdip and through several large rift chambers. These tributaries converge before entering a much larger vadose canyon, which is up to 5 m high and wide. The passage then swings round to the west, following a predominantly strike-orientated course, with many minor offsets on cross joints, as far as a sediment choke. The whole system shows very close joint control of its passages. There are extensive breakdown deposits but very few speleothems.

The swallet system of GB Cave lies at the foot of a short blind valley which ends on the limestone boundary (Figure 5.8). It contains almost 2000 m of passages (Figure 5.3) extending to a depth of 135 m. A number of small inlets near the entrance converge on the head of the main streamway. The passage from the Gorge to the Main Chamber is the largest in a Mendip cave, a vadose canyon in places more than 10 m high and wide. It contains massive banks and terraces of sediment and breakdown debris (Figure 5.4), and descends steeply to a sediment choke. Extensive inlet passages and several oxbows on its western side are smaller but mimic the overall morphology. Rhumba Alley and some of the inlet passages near the entrance show clear evidence of initial phreatic development, and a phreatic half-tube is visible in the roof in parts of the Gorge. From the south end of Main Chamber several much smaller distributary passages branch off. These have a much more gentle gradient and show clear morphological evidence of phreatic development below the water table. Above the downstream choke one of these abandoned distributary passages extends to further chokes and the Great Chamber, 50 m in diameter and extensively modified by roof collapse and upward stoping.

Many of the passages in GB Cave show close geological control, with the dip of 25° influencing the profile, and joints and faults dictating the plan relationship of the various passages. Throughout the cave, speleothems of various types are abun-

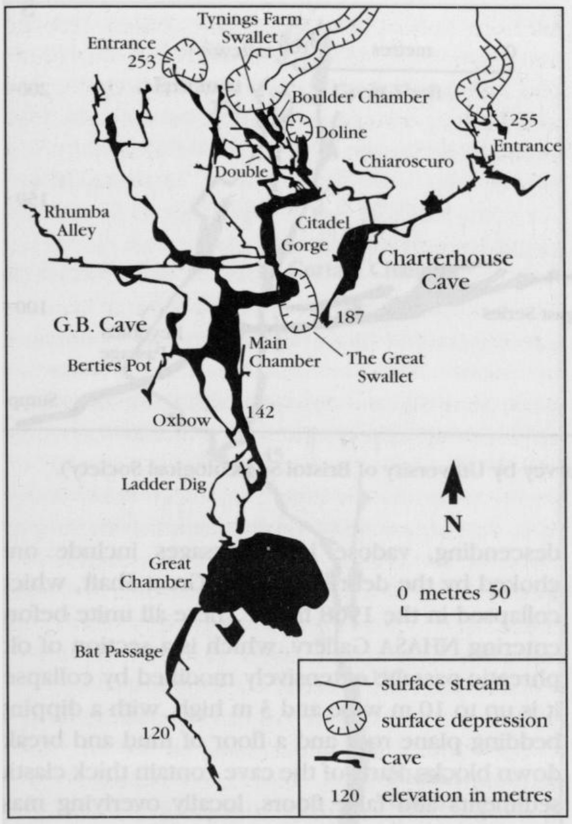

Figure 5.3 Outline map of GB Cave, Charterhouse Cave and the main surface features above them (from survey by University of Bristol Speleological Society).

dant, some of them formed of aragonite or interlayered calcite and aragonite. In addition there are extensive clastic deposits interbedded with stalagmite layers and recording episodes of erosion and deposition. Major flooding in July 1968 modified parts of the system considerably, blocking at least one of the inlet passages, causing surface collapse into the northern end of the Gorge and causing extensive scouring and redeposition of some sediment sequences. Dating of stalagmite and sediment sequences (Atkinson *et al.*, 1978; Farrant, 1995) has revealed evidence of at least four phases of speleothem growth timed at about >330, 170–120, 63 and <13 ka.

Adjacent to GB Cave lies Charterhouse Cave (Figure 5.3). This resembles GB in having a series of small inlet phreatic tubes leading into a main streamway, the Citadel, which has been greatly enlarged by vadose erosion. The cave is essentially part of GB, but there is no passable connection between the two. It also contains thick clastic sediment deposits and is exceptionally well decorated with speleothems. Both GB and Charterhouse Caves lie below a shallow dry valley where successive stages of fill have choked old sinks and thereby generated multiple sink passages on diversionary routes which coalesce underground.

Longwood Swallet lies in the floor of one of the main valleys which are tributary to Cheddar Gorge

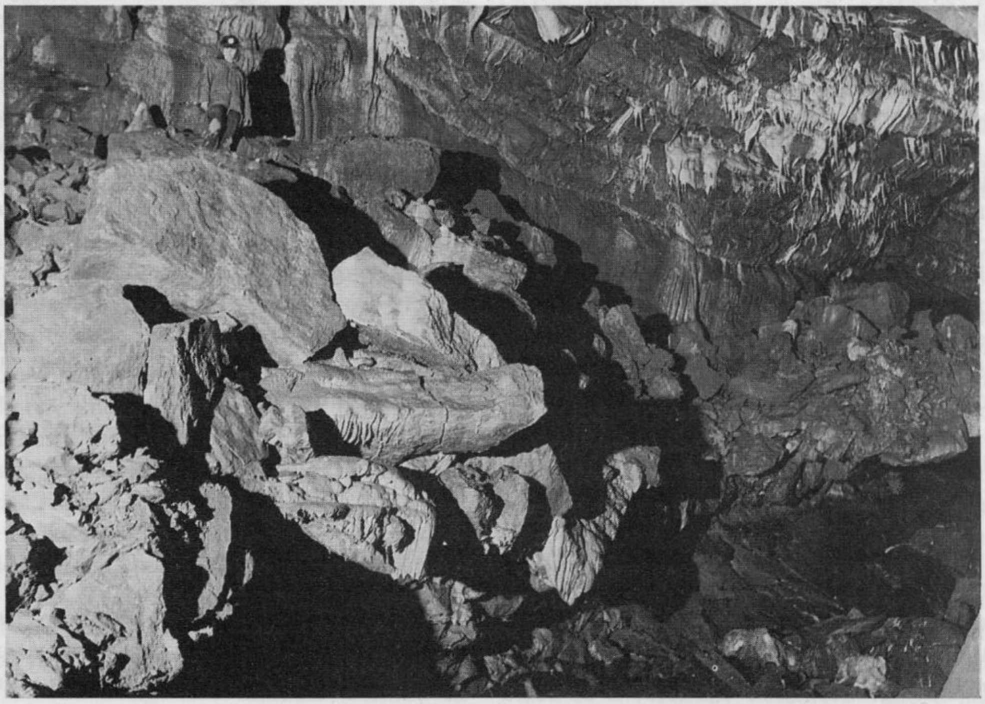

Figure 5.4 Massive banks, terraces and false floors of coarse breakdown, clastics and stalagmite flowstone in the Gorge of GB Cave. (Photo; A.C. Waltham.)

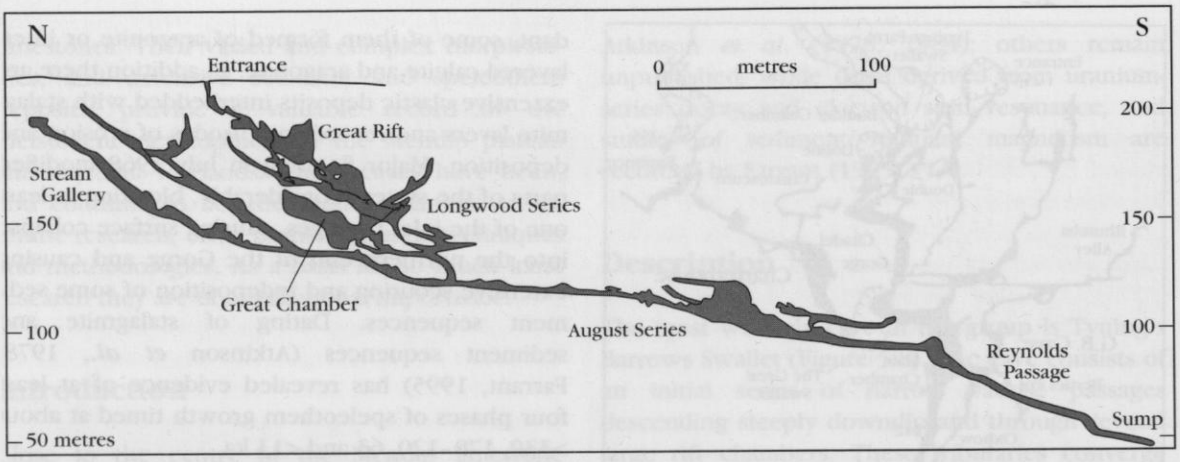

Figure 5.5 Extended profile of Longwood Swallet (from survey by University of Bristol Speleological Society).

(Figure 5.8). It contains over 1600 m of cave passages, reaching to a depth of 175 m. A natural shaft in the valley floor leads to a complex series of passages with several large chambers developed on faults and enlarged by collapse (Figure 5.5). Evidence of an extended phase of early high-level phreatic development is seen in the presence of tubes, loops and avens with crests at the same height. Lower down the cave these passages converge on a steep fault-controlled rift descending to the main streamway. This extends for more than 500 m along mainly vadose canyon passage often only a metre or so wide but of considerable height and with phreatic remnants preserved in places. Upstream, separate tributary passages have been followed to chokes a short distance below the surface sinks. Downstream the known cave ends at a sump beyond a series of very narrow joint-guided rift passages. Although the system contains relatively few speleothems there are extensive clastic sediment deposits containing interbedded stalagmite layers.

Rhino Rift consists essentially of a single series of vadose shafts developed along a fault and adjacent joints and descending to a small, choked phreatic tube at a depth of 145 m. The entrance lies in a tributary valley below Longwood Swallet, some distance south of the boundary between the Black Rock Limestone and the underlying shales (Figure 5.8). The cave contains extensive collapse debris but relatively little finer clastic material or speleothems. Dating of flowstone indicates that the cave has been in existence for at least 75 000 years (Atkinson *et al.*, 1984).

Manor Farm Swallet lies at the next sink to the east (Figure 5.8), and has over 900 m of passage (Figure 5.6). A series of fairly small, steeply descending, vadose inlet passages include one choked by the debris from the Great Shaft, which collapsed in the 1968 flood. These all unite before entering NHASA Gallery, which is a section of old phreatic passage extensively modified by collapse; it is up to 10 m wide and 3 m high, with a dipping bedding plane roof and a floor of mud and breakdown blocks. Parts of the cave contain thick clastic sediments and false floors, locally overlying massive gour barriers and flowstone. There are many stalactite curtains and banks of active flowstone.

A large stream sinks in the Blackmoor Valley (Figure 5.8), but the associated cave system has yet to be discovered. Several smaller cave systems have been found, including Blackmoor Flood Swallet, Waterwheel Swallet (Stanton, 1987) and Grebe Swallet. The latter is important as it contains evidence for the origin and emplacement of the lead ores in the Mendip Hills (Stanton, 1991).

Charterhouse Warren Farm Swallet (Levitan *et al.*, 1989), lies to the south of the Velvet Bottom valley (Figure 5.8). It is entered via a narrow shaft which drops into a series of phreatic passages, much modified by collapse, speleothem deposition and the influx of clastic material. The site is an important archaeological site and its position is intermediate between the Charterhouse swallet caves and the Cheddar resurgence.

Interpretation

The caves developed on the southern flank of the Blackdown pericline include classic examples of vadose caves developed in dipping limestone. They show a wide range of morphologies from the massive canyon passage in GB Cave to the

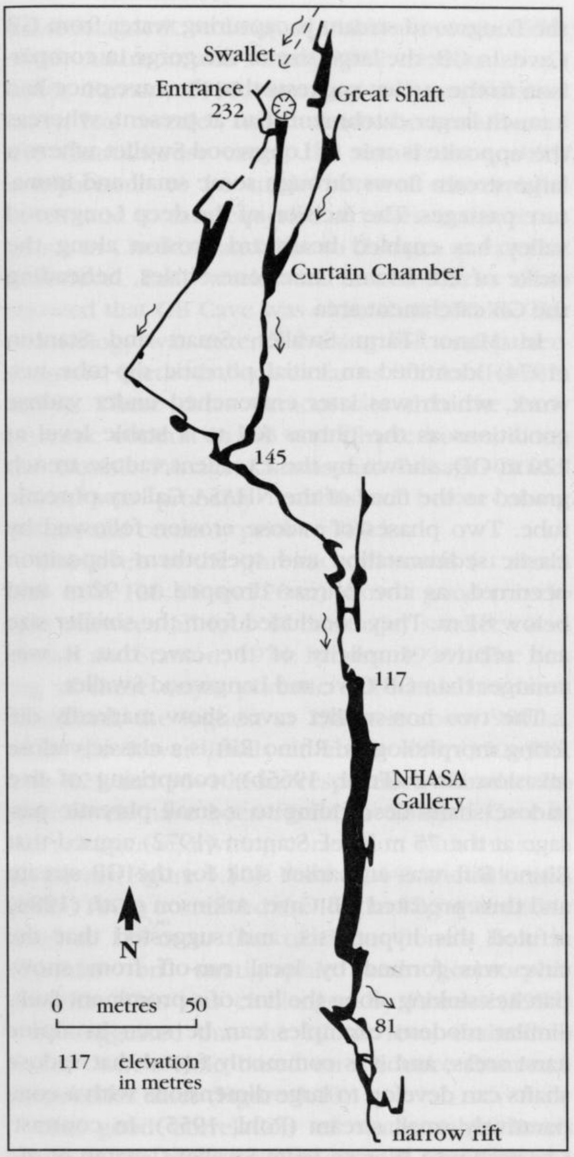

Figure 5.6 Outline map of Manor Farm Swallet (from survey by University of Bristol Speleological Society).

fault-guided rifts in Longwood Swallet. The smaller cave of Charterhouse Warren Farm Swallet is the only one known on the Mendip Hills which is intermediate between the predominantly vadose swallet caves and the largely phreatic caves at the resurgence.

All the major swallet streams were dye tested to the Cheddar Risings with travel times between 16 and 48 hours (Atkinson *et al.*, 1967; Drew, 1975a). Pulse wave tests at Longwood Swallet (Smart and Hodge, 1979) indicate that at low flow, only 9% of the Longwood–Cheddar conduit is vadose. Repeated dye tests at several sites on the Mendips included Longwood Swallet to demonstrate that the travel time is inversely proportional to resurgence output (Stanton and Smart, 1981). The presence of up to three fluorescein peaks for each trace suggests the possibility of several alternative conduits to the resurgence. The identification of a common resurgence at Cheddar has enabled the evolutionary history of the swallet caves to be compared and their response to base-level change at the resurgence examined.

Geomorphology

The Charterhouse caves display many of the features common to the typical Mendip cave. All the swallet caves exhibit complex passage networks developed predominantly downdip and extensively modified by vadose erosion, sedimentation and collapse. Many of the caves provide excellent evidence of structural control. Joint direction is the dominant control, and is clearly recognizable on cave plans (Figures 5.3, 5.6). Over 80% of the passages in Manor Farm Swallet are joint controlled (Smart and Stanton, 1974). Bedding plane control is shown by the downdip orientation of many of the passages while faulting is especially important in the formation of large chambers, notably in Longwood Swallet and vadose shafts such as Rhino Rift. All the swallet caves are developed at the base of the Black Rock Limestone.

The most westerly of the caves is Tyning's Barrow Cave. Although not a true stream sink, its morphology is similar to the swallet caves. Admirable structural control is shown in the lower streamway where downdip joint-controlled segments are linked by strike-orientated passages.

The most complex of the swallet caves and one of the most intensively studied is GB Cave, genetically related to the adjacent Charterhouse Cave. The geomorphology of GB Cave was first studied in detail by Ford (1964), who elevated it to his type example of a vadose drawdown swallet cave. He envisaged an initial period of phreatic erosion forming a complete passage network. This was followed by alternating phases of vadose drawdown, erosion, clastic sedimentation and speleothem deposition along the outline plan established during the initial phreatic phase. The water tables were initially controlled by the lack of cave development, but fell rapidly to a stable base level once a mature cave system had been established. Thus vadose cave development took place in a vertically extensive vadose zone, the sequence of captures and trenches being unrelated to base-level lowering.

The discovery of the neighbouring Charterhouse Cave enabled Smart *et al.* (1984) to test Ford's hypothesis. They concluded that rather than an initial period of phreatic development, followed by rapid base-level lowering and vadose drawdown, base-level probably fell slowly and intermittently, thus deepening the vadose zone slowly through time. During this period, passage morphologies reflect the transition from phreatic, through paraphreatic to entirely vadose conditions, which ultimately led to the abandonment of the strike-orientated pressure-fed phreatic conduits in favour of free-draining vadose dip tubes and joint-guided rifts. Initially the only mature phreatic conduits were along the Double Passage–Chiaroscuro Passage–Citadel route and the Rhumba Alley–Berties Pot–Ladder Dig route. The sequence of trenches in Charterhouse can be related to the declining water table level. Both Ford (1964) and Smart *et al.* (1984) recognized two major phreatic rest levels in the GB–Charterhouse system; in Double Passage at 238 m and a second just above Ladder Dig at 137 m. The multiplicity of inlet passages reflects the large number of sinks the stream has utilized through time, caused by the infilling of former sinks by clastic material and the opening of new ones when the loess cover was eroded.

The hydrology of GB Cave has been studied in some detail. D.C. Ford (1966) found that the calcium hardness of dripwaters varied by up to 50 ppm. Stenner (1973) showed that the increase in solute load in the GB Cave stream was not due to direct solution of calcite by the stream water, but was the result of admixtures of waters with higher calcium contents. Friederich and Smart (1981, 1982) studied the water in the vadose zone and based their classification of autogenic percolation waters on samples taken from GB Cave.

Longwood Swallet was studied in detail by Atkinson (1967). He suggested that initial phreatic erosion was followed by a fall in the water table by 56 m, thus initiating vadose erosion. He identified three further aggradation and two renewed vadose incision stages corresponding to further drops in base level, compared to the two identified by Ford (1964) in GB Cave. On this evidence, he concluded that Longwood was older than GB. Atkinson identified three phreatic rest levels in Longwood Swallet, at 138–141 m, 120–123 m and 90–93 m. There is slender evidence for a fourth at 70 m. The modern phase of vadose erosion is graded to a water table at 40 m. It is clear from their contrasting morphologies that the Longwood stream is capturing water from GB Cave. In GB, the large size of the gorge in comparison to the stream suggests that the cave once had a much larger catchment than at present, whereas the opposite is true in Longwood Swallet where a large stream flows through some small and immature passages. The incision of the deep Longwood valley has enabled headward erosion along the strike of the Lower Limestone Shales, beheading the GB catchment area.

In Manor Farm Swallet, Smart and Stanton (1974) identified an initial phreatic dip-tube network, which was later entrenched under vadose conditions as the phreas fell to a stable level at 120 m OD, shown by the excellent vadose trench graded to the floor of the NHASA Gallery phreatic tube. Two phases of vadose erosion followed by clastic sedimentation and speleothem deposition occurred, as the phreas dropped to 92 m and below 81 m. They concluded from the smaller size and relative simplicity of the cave that it was younger than GB Cave and Longwood Swallet.

The two non-swallet caves show markedly differing morphologies. Rhino Rift is a classic vadose invasion cave (Ford, 1965b), comprising of five vadose shafts descending to a small phreatic passage at the 75 m level. Stanton (1972) argued that Rhino Rift was an earlier sink for the GB stream and thus predated GB Cave. Atkinson *et al.* (1984) refuted this hypothesis, and suggested that the cave was formed by local run-off from snowpatches sinking along the line of a prominent fault. Similar modern examples can be seen in alpine karst areas, and it is commonly found that vadose shafts can develop to large dimensions with a comparatively small stream (Pohl, 1955). In contrast, Charterhouse Warren Farm Swallet (Levitan *et al.*, 1989) is dominantly phreatic and represents an important link between the Charterhouse swallet caves and the resurgence in Cheddar. It consists of a remnant of phreatic passage which functioned as a major strike integrator when the regional base level was at or above 227 m. Three types of sediment fill in the cave include a siliceous allochthonous gravel derived from the Blackdown pericline, several calcareous allochthonous fills, and limestone breakdown. The calcareous fills are especially important as they contain profuse archaeological remains (Levitan *et al.*, 1989).

Geochronology

Dating of the cave sediments, using uranium-series, electron spin resonance (ESR) and palaeomagnetic techniques (Atkinson *et al.*, 1978, 1986; Atkinson and Smart, 1982; Levitan *et al.*, 1989; Farrant, 1995; Smart *et al.*, unpublished data), has revealed much about the evolution of the Charterhouse caves; the data have enabled comparisons to be made between the swallet caves, and to the sequence of caves at the resurgence in Cheddar, and thus to changes in external base level. Early work with uranium-series dates showed that GB Cave was older than 350 ka. The chronology was extended using ESR and palaeomagnetic methods back as far as 900 ka (Farrant, 1995). These dates demonstrate that the early phreatic conduit in GB and Charterhouse, along the Double Passage–Chiaroscuro Passage–Citadel route, was probably established before about 900 ka and certainly prior to 780 ka.

The levels of the phreatic still-stands (at about 238, 138, 120, 90 and 70 m) show a good correlation between all four of the major swallet caves (Smart and Stanton, 1974; Farrant, 1995). The timing of these major phreatic still-stands has been estimated; the highest at 238 m is about 900 ka, with the lower levels at about 480, 350–380, 200–225 and 95–100 ka, respectively. Similar distinct levels have been found in Gough's Cave at the resurgence, inviting correlation with the swallet caves (Figure 5.10). Ford (1964) and Atkinson *et al.* (1978) correlated the Ladder Dig water table level at 138 m to that of Great Oone's Hole in Cheddar on stratigraphic and geomorphic grounds. This was challenged by Farrant (1995) who suggested that the 120 m level drained to Great Oone's Hole based on evidence from uranium-series dates (Figure 5.10).

The good correlation of water table levels between the major swallet caves at Charterhouse suggests they underwent a uniform response to changes at the resurgence. This response is driven by progressive base-level changes at the resurgence which propagate up the conduit. The rate of propagation is controlled by the abandonment and capture of phreatic links at the resurgence (Smart *et al.*, 1984). This correlation is not so clear in the Priddy caves, where the swallet caves have markedly contrasting morphologies. This is probably because the Priddy–Wookey system responds slower to base-level lowering; it has yet to fully respond to the last phase of base-level lowering, as active vadose incision of the earlier phreatic loop crests is still progressing.

Thick, coarse, angular, sandstone and limestone gravel fills occur in all the swallet caves. At many places, stream erosion has undercut these cemented gravels leaving perched false floors. The gravels were emplaced under periglacial conditions by the transport of frost-shattered surface material into the cave by solifuction and debris flow events. The associated speleothem was deposited in the intervening warmer periods when increased biogenic soil activity raised the carbon dioxide levels in the soil, causing saturation of the percolation groundwater and stalagmite deposition. In GB Cave, several generations of fills are recognized, interbedded or capped with calcite flowstones which have been dated. At least eight major gravel fills have been identified in a complex sequence of gravel emplacement and speleothem deposition (Figure 5.7). Within the limits of the available dating, the phases of gravel emplacement appear to correspond with the cold stages of the Pleistocene. Stratigraphical relationships show that similar, complex sequences occur in Charterhouse Cave,

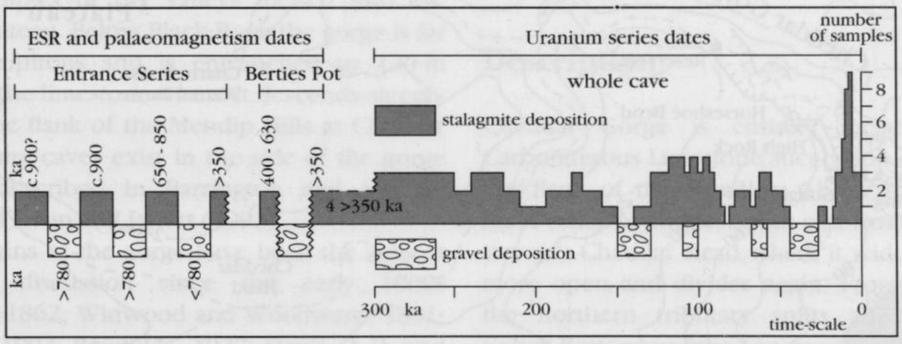

Figure 5.7 Phases of stalagmite and gravel deposition in GB Cave, with a chronology based on stalagmite dates obtained from uranium-series, ESR and palaeomagnetic techniques (after Farrant, 1995). Stalagmite ages are represented covering the error bars on the dated samples; actual time spans of the deposition phases may be smaller, but data from stalagmites as yet undated may increase the lengths of the deposition phases.

Longwood Swallet and Manor Farm Swallet, but have yet to be dated. However, the dangers of trying to elucidate the developmental history of the cave from the clastic sequences alone were highlighted by the profound changes wrought by the 1968 flood (Hanwell and Newson, 1970).

Conclusions

The Charterhouse caves provide some of the finest examples of cave development in dipping limestones. The cave morphology, clastic sediments and speleothems are the most intensively studied in Britain, and have far-reaching implications for the study of cave development, karst hydrology and Pleistocene chronology. The wealth of dated sediment and speleothem has enabled the construction of a remarkably long chronology and an elucidation of the geomorphic history of the Mendip Hills. The correlation of water table levels in the swallet caves with those at the Cheddar caves demonstrates the role of base-level control at the resurgence on the whole conduit system. Although the designation of some of the caves as type sites has been challenged, the pioneering nature of the underground work renders the Charterhouse caves of international importance.

CHEDDAR GORGE

Highlights

Cheddar Gorge is perhaps the single best known karstic feature in Britain and provides a spectacular example of a limestone gorge fed by a system of dry feeder valleys. The morphology of the gorge and the associated well-dated caves, provides a unique insight to its geomorphic evolution over the last million years. It demonstrates the results of episodic fluvial erosion in a karst terrain, which was left dry when the surface drainage disappeared underground into caves.

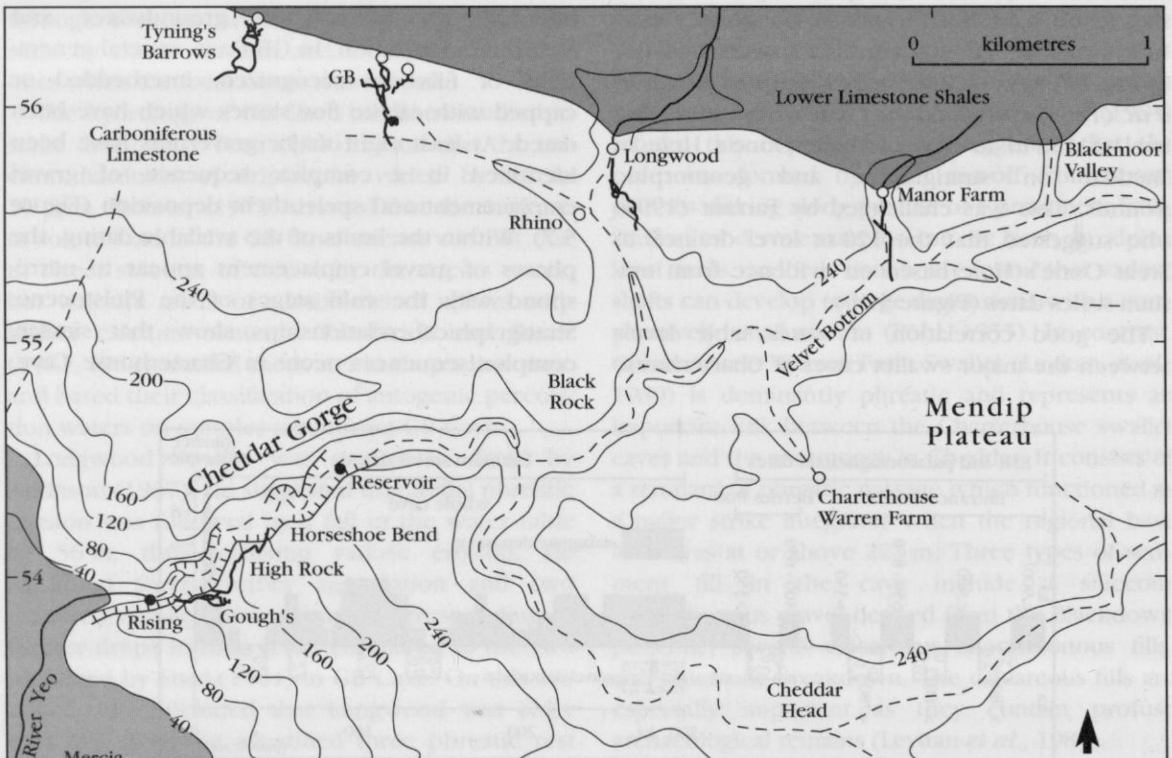

Figure 5.8 Map of Cheddar Gorge and the lower part of its dry valley system reaching across the karst to the edge of the Mendip Plateau.

Figure 5.9 Cheddar Gorge, looking upstream from the northern rim opposite High Rock. The limestone dips to the right, ensuring the stability of the cliffs on the right, while the left slope is cut back almost to the dip of the bedding planes. (Photo: A.C. Waltham.)

Introduction

Cheddar Gorge extends approximately 2 km eastwards from Cheddar village and forms the downstream portion of an extensive dry valley network which once drained most of the Mendip plateau (Figure 5.8). Above Black Rock three dry valleys form part of the dendritic network feeding into Cheddar Gorge. These represent particularly good examples of dry valleys incised into the Mendip plateau. Below Black Rock the gorge is far more precipitous and is entrenched to 120 m deep into the limestone where it descends steeply towards the flank of the Mendip Hills at Cheddar village. Many caves exist in the side of the gorge and are described in Barrington and Stanton (1977) and Irwin and Jarratt (1992).

The origins of the gorge have been the subject of much discussion since the early 1800s (Dawkins, 1862; Winwood and Woodward, 1891; Callaway, 1902; Reynolds, 1927; Stride, A.H. and Stride, R.D. 1949; Ford and Stanton, 1968; Trudgill, 1977; Smith, 1975a, b, 1977), with several theories including cavern collapse, earthquake activity, and incision by a periglacial meltwater river being put forward. Only the last of these now carries any credence. Recent work by Atkinson *et al.* (1978), Atkinson *et al.* (1986), Smart *et al.* (1988b) and Farrant (1995) has focused on the morphology and dating of both the swallet caves and the caves exposed in the gorge, which has led to a better understanding of the geomorphic history of the gorge, and enabled it to be set in a chronological framework.

Description

Cheddar Gorge is entirely incised into the Carboniferous Limestone succession on the southern flank of the Mendips. Above the gorge the main valley continues south-east from Black Rock, towards Cheddar Head where it widens, becomes more open and divides again. From Black Rock, the northern tributary splits and extends up Velvet Bottom and the Longwood valley, as far the modern stream sinks at Longwood swallet and the other Charterhouse caves, which lie at the contact of the limestone with the Lower Limestone Shales on the south side of the Black Down pericline.

The Longwood–Cheddar valley is the best example of the relationship between the stream sink, dry valley and resurgence (Figure 5.8). The upper dry valleys descend gently from the plateau surface at an elevation of around 245 m to Black Rock, where the gradient increases markedly. Over the next 2 km the floor descends over 130 m to an elevation of 20 m at the resurgence (Figure 5.10).

The rock exposed in the gorge is mainly the Clifton Down Limestone, although some Hotwells Limestone crops out in the cliffs of the downstream part. The limestone dips at about 20° to the south and is cut by a major joint set trending NNW–SSE which has a strong influence on the cliff morphology and on the caves. The cliffs on the south side reach heights of 120 m, and are dominantly vertical, mainly aligned on the strong joints, and broadly stable because the dip is away from the gorge and into the cliffs. The northern side is less steep, because the southerly dip facilitates bedding plane slip and the formation of steep bedding plane slabs. The cross-section of the gorge is therefore an asymmetric V-shape, typical of fluvial excavation (Figure 5.9). Its floor meanders between rock buttresses whose pattern is at least in part orientated by the major fractures which also determine the profiles of the main limestone walls. The gorge is now dry, except in major floods such as that of July 1968 (Hanwell and Newson, 1970), and the drainage is entirely underground, the water resurging at the Cheddar Risings at the foot of the gorge.

In the gorge walls are a number of caves, the most important of which are the Gough's Cave complex, clustered around the resurgence at the foot of the gorge, and Reservoir Hole. Many of these contain stalagmites which have been dated by uranium-series and electron spin resonance methods. Stalagmites in the upper parts of Gough's Cave give uranium-series ages around 235 ka (Farrant, 1995). A scalloped flowstone in Great Oones Hole above yielded uranium-series ages around 375 ka (Farrant, 1995), but an electron spin resonance date for some of the same flowstone yielded an age of 1060 ka (Smart *et al.*, 1988); the latter is probably an overestimate, reflecting uncertainties in the dosimetry. It is apparent that the Gough's main bore was abandoned by around 120 000 years ago. Uranium dates from Reservoir Hole show the upper cave levels had been abandoned by 350 ka. The gorge shows many classic features of a fluvially excavated valley. These include a steep long profile, a recognizable V-shaped cross-section, a clear relationship to normal fluvial valleys, lack of any collapse debris, knickpoints including a conspicuous one at Horseshoe Bend, and a large alluvial fan dissected by the modern streams at the foot of the gorge.

Interpretation

Cheddar Gorge is Britain's largest and most spectacular karst gorge. It provides a particularly fine and easily accessible example of fluvial erosion in a karst landscape, although this was not always thought to be the case. The earliest theories on the formation of the gorge were put forward by Dawkins (1862) who suggested that it was formed as a result of cavern collapse. This was also the view held by Winwood and Woodward (1891) in an account of a Geologists' Association field excursion to Mendip. Later, Callaway (1902) noted the joint-controlled nature of the gorge and concluded that it must have been formed by a subterranean stream. Reynolds (1927) was one of the first to suggest that the gorge was cut by a surface river. The last advocates of the collapsed-cavern theory were Stride, A.H. and Stride, R.D. (1949), although this myth is still often perpetuated in many modern geological texts. Thus Cheddar Gorge is probably Britain's most frequently misinterpreted geomorphic feature.

It is possible that some subaerial fluvial excavation took place before karstification had developed sufficiently to divert drainage underground. However, this process cannot have played a major role as the gorge truncates older high-level caves. Ford and Stanton (1968) demonstrated that the gorge must have been formed by a subaerial stream, pointing to the difference between the gorge's long profile and that seen in the stream caves. They also noted that the gorge has often cut cleanly through existing cave passages. Additionally, they stressed the disparity between the immense volume of the gorge and that of even the largest Mendip caves such as GB and Lamb Leer. Cavern collapse can only have played a minor, if not trivial role in the gorge formation. A useful summary of the different theories on the origins of the gorge is published in Smith (1975a).

The commonly accepted view is that Cheddar Gorge was incised over the last million years by a subaerial meltwater river during periglacial periods, when underground drainage was restricted

(Smith, 1975a). Extensive mass movement and solifluction, coupled with development of permafrost during glacial periods led to the blocking of the swallet caves with ice and frozen mud and the establishment of surface drainage. Due to the nature of the Mendip plateau, the steepest stretches were at the valley mouth, where incision was therefore the greatest. Cheddar Gorge is the largest of the gorges on the Mendips because it drained the bulk of the plateau and because its lower end was lower than those elsewhere, thus maximizing its erosive power. Each successive periglacial episode caused renewed incision of the gorge, while during the interglacial periods, underground drainage was renewed and the gorge became dry, except under conditions of major flood. A late Pleistocene fauna in several of the valley floor caves (Tratman, 1975; Currant, 1987) shows that the gorge had reached almost to its present floor level by early Devensian times.

Erosion of the softer Jurassic and Triassic rocks along the southern flank of the Mendips during interglacials enabled each successive reactivation of the valley to work from a lower level, thus creating a series of knickpoints in the gorge which receded upstream through time (Barrington and Stanton, 1977). The knickpoints have been correlated on geomorphic grounds with a series of erosional benches along the southern flank of Mendip (Ford and Stanton, 1968). However, these erosional benches may not accord with the former positions of base level; Stanton (1985) reinterprets them as random associations of stratimorphic flats. These knickpoints may also correlate with a series of abandoned cave levels in the Gough's Cave system (Ford, 1965b; Ford and Stanton, 1968; Stanton, 1985; Farrant, 1991). The cave levels relate to a succession of past stable resurgence positions (Figure 5.10); they may also correlate with levels in the swallet caves to the north, but more dating evidence is needed before conclusions can be drawn.

Recent work has concentrated on defining the rate of excavation of the gorge, its development through time, and how it relates to the climate fluctuations during the Pleistocene. By dating the caves and relating their morphology to former stages in the evolution of the gorge, Atkinson *et al.* (1978) and Farrant (1991, 1995) have shown that the lower section of the gorge has been incised at an average rate of 0.25 m ka^{-1}. Extrapolation of this rate up to the plateau surface suggests incision of the gorge began approximately a million years ago. With refinement of a chronology it may prove possible to ascertain the relative importance of periglacial erosion and temperate fluvial erosion, but low resolution of the older dates makes this very difficult for the earlier phases of the gorge's history. The large number of dated stalagmite samples from extensive associated caves makes this one of Britain's best documented karst gorges.

Conclusions

Cheddar Gorge is the largest and most spectacular karst gorge in Britain, and is unique in that a series of well-dated caves in the gorge walls have enabled its geomorphic evolution to be deduced. Although often wrongly cited as a collapsed cavern, it is a fine example of fluvial erosion in a karst landscape, left dry by the onset of underground drainage. Cheddar clearly shows the relationship between the gorge and the dry valleys which feed it, while the abandoned and active caves show the relationship between surface and underground features in a limestone karst.

CHEDDAR CAVES

Highlights

The Cheddar caves show the development of successively lower passages to a sequence of resurgences; these formed at positions dictated by the lowering of a periglacial surface drainage route which constituted the local base level. The main upstream river cave is aligned with the dip, and provides a fine example of phreatic loops developed on joints and bedding planes in dipping limestone. Downstream of this, distributary passages, aligned on the strike, demonstrate the role of local geological structures.

Introduction

The Cheddar caves are located in the walls and beneath the floor of the lower end of Cheddar Gorge (Figure 5.1). A number of caves represent fragments of a single extensive system. Cheddar Rising, the outlet for the active cave system associated with the Cheddar Gorge, is the largest resurgence in the Mendip Hills. Allogenic water drains off the Old Red Sandstone slopes on the south side of Blackdown Hill, entering sinks in the

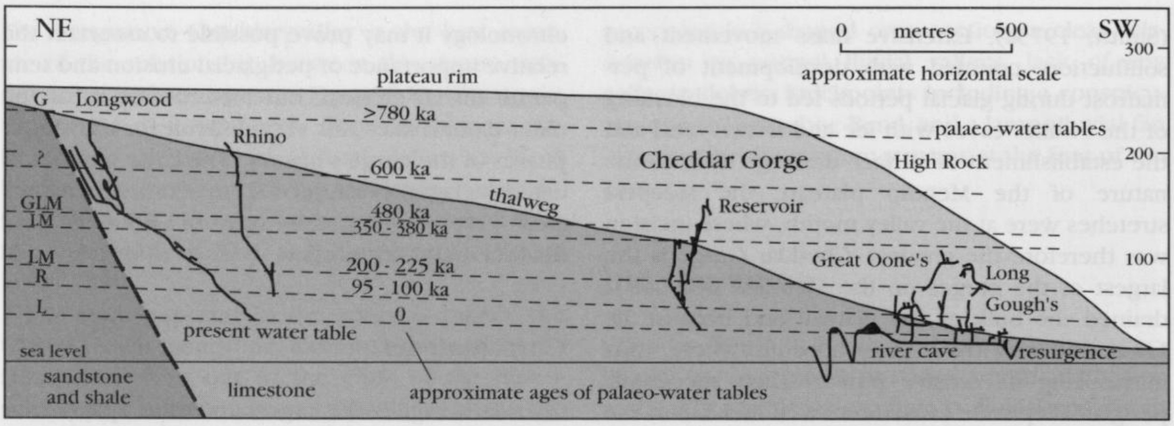

Figure 5.10 Long profile of Cheddar Gorge up into the Longwood Valley, with the caves beneath. Each palaeo-water table is recognized from cave and surface morphology, and is dated from the sediments in associated cave passages at both the swallet and resurgence ends of the system. The water tables steepen greatly in the sandstone and shale, but are marked beyond the limestone only to label the caves in which each is recorded (G = GB Cave; L = Longwood Swallet; M = Manor Farm Swallet; R = Rhino Rift). The horizontal scale is distorted by the projection, and the vertical scale is exaggerated three times (largely after Stanton, 1985; Farrant, 1995).

Charterhouse area, 3 km to the north. A second group of sinks feeding to the Cheddar resurgence lies up to 11 km to the east, draining the northern limb of the North Hill pericline (Figure 5.1). Atkinson (1977) identifies the drainage system as an important example of conduit flow with diffuse input and storage. The explored caves at the resurgence end of the system are developed largely along the southern flank of the gorge, with the most extensive section, Gough's Cave, located at the lower end of the gorge immediately adjacent to the active risings.

The Cheddar caves have been the subject of many popular and scientific publications. Descriptions of the caves are given in Barrington and Stanton (1977) and Irwin and Jarratt (1992), with a more detailed account of discoveries in the river cave given by Palmer (1988) and Stevenson and Palmer (1986). Aspects of the hydrology are discussed by Atkinson (1977), Drew (1975a), Drew *et al.* (1968), Smart (1981), Smart and Hodge (1980) and Smith and Newson (1974). The history of development of the cave systems has been discussed at length by Ford (1965b, 1968), Drew (1975b), Stanton (1985) and Farrant (1991). Aspects of the sediments contained within Gough's Cave have been the subject of papers by Collcutt (1985) and Leroi-Gourhan (1985). There have been many publications concerned with the Pleistocene fauna recovered from excavations in the Cheddar caves; these have been reviewed by Jacobi (1985).

Description

The most extensive caves in Cheddar Gorge lie close to the present resurgence. Numerous other caves have been explored, most of which probably are connected with Gough's Cave in some way. The most important of these are Great Oone's Hole, Long Hole and Reservoir Hole (Figure 5.10).

Gough's Cave, together with Great Oone's Hole and Long Hole (Figures 5.10 and 5.11), contains more than 2200 m of explored passage developed over a total vertical range of more than 180 m. Part of the system is currently operated as a show cave. The lowest part of Gough's Cave is the active river cave, a phreatic tube typically 5 m wide and 3 m high. Upstream, the River Cave forms a series of deep phreatic loops on a north–south alignment (Figures 5.10 and 5.11). In each loop, the river flows under pressure almost straight down the dip of bedding planes and then rises through vertical rifts aligned on joints. The loops reach depths of up to 58 m, more than 30 m below present sea level. Vadose incision by the river has cut a loop crest to leave the Bishop's Palace chamber, which rises to almost 30 m above the present river level, partly due to upward stoping of the roof. The flooded passages are up to 7 m wide and 2 m high, and contain laminated mud sediments which are being re-excavated by the river. Downstream, the river passes through Lloyd Hall, a rift chamber 20 m long and 12 m

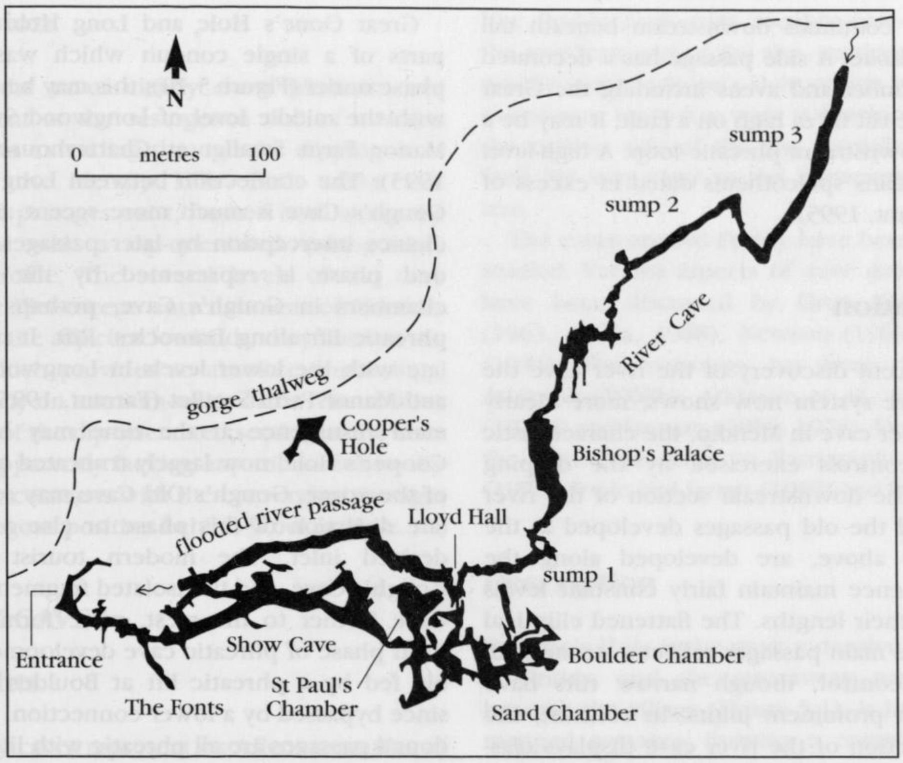

Figure 5.11 Outline map of Gough's Cave, Cheddar. Long Hole and Great Oone's Hole lie partly over the show cave section and are omitted for clarity (from surveys by Wessex Cave Club and Cave Diving Group).

high with a roof connection to the cave level above; it then continues to a choke close to the resurgence.

The lowest of the abandoned levels lies at about 45 m OD, about 18 m above the river cave, and includes much of the show cave (Figures 5.10 and 5.11). Part of the tourist route follows a magnificent phreatic tube of similar dimensions to the active river passage almost directly below. Phreatic solution along the NNW–SSE joints, has created cross rifts and avens up to 30 m high. The large gour pools of the Fonts occupy a side passage, and speleothems are abundant at several points within this level. Speleothem dates from this level (Farrant, 1995) indicate an age in excess of 120 ka. The passage terminates at a large chamber above Lloyd Hall, but further caves at this level are known to extend west from the lower part of Boulder Chamber.

Boulder Chamber has high-level, tall chambers and rifts, well decorated with speleothems in places, linked by largely sediment-filled passages at about 60 m above sea level; speleothem dates indicate an age of more than 230 ka (Farrant, 1995). Excavations in the floor of Boulder Chamber revealed a narrow shaft, filled with boulders and clastic sediment, which once formed an inlet to the system (Stanton, 1965).

The highest level in the Gough's Cave system is represented by Great Oone's Hole and Long Hole, both of which lie almost directly above parts of the lower levels. Flowstone with a uranium-series date of 380 ka (unpublished) lies in Great Oone's Hole, which has 150 m of abandoned phreatic passage opening in the side of the gorge more than 60 m above the show cave entrance. Beyond a level section the passage gently descends to a choke close above one of the chambers in the back of Gough's. Long Hole, with 260 m of passages, probably represents a downstream continuation of Great Oone's Hole. Descending rifts connect to chambers in Gough's Cave, while the main cave ascends to passages on the same level as Great Oone's Hole choked close to the present surface.

Reservoir Hole lies on the southern side of the gorge upstream and north-west of Gough's Cave (Figure 5.10); it covers a vertical range of 123 m and descends to within 8 m of resurgence level. A descending series of small tubes and tall vertical rifts intercepts an abandoned stream passage 6 m wide containing mud formations and thick sediments. This continues downstream beneath tall avens to a choke. A side passage has a decorated collapse chamber and avens including the Great Aven, a wide rift 60 m high on a fault; it may be a truncated downstream phreatic loop. A high-level passage contains speleothems dated in excess of 350 ka (Farrant, 1995).

Interpretation

With the recent discovery of the river cave the Gough's Cave system now shows, more clearly than any other cave in Mendip, the characteristic geological controls exercised by the dipping limestone. The downstream section of the river cave, and all the old passages developed at the three levels above, are developed along the strike and hence maintain fairly constant levels throughout their lengths. The flattened elliptical shapes of the main passages reflect a strong bedding plane control, though narrow rifts have developed at prominent joints. In contrast, the upstream section of the river cave displays classic dip-orientated development in inclined limestone, with deep phreatic loops caused by the passage following the bedding downdip before rising vertically up joint-guided rifts. The close superimposition of the three levels of old strike passage above the present active river passage suggests that their position has been controlled by a major east–west zone of fracturing and minor folding which has coincided with the available outlet position in the gorge floor.

Ford (1965b, 1968) and Farrant (1991) have identified at least four distinct levels within the strike-orientated part of the Gough's Cave system. These have been interpreted as zones of mature, shallow phreatic cave development formed sequentially below four base levels, possibly recognizable also as surface terraces (Ford and Stanton 1968; Stanton 1985). No evidence has been found for any higher levels of development in the dip-orientated upstream section of the river cave, suggesting that these upper three levels were all fed by phreatic lifts towards the eastern end of the strike passages. There are at least two abandoned phreatic lifts from the River Cave into the upper levels of Gough's Cave, but the size of these appears inconsistent with the flow which they would have had to transmit, and the ancient strike passages may have been fed by other, unknown, dip passages (Farrant, 1991, 1995).

Great Oone's Hole and Long Hole represent parts of a single conduit which was the first phase outlet (Figure 5.10); this may be correlated with the middle level of Longwood Swallet and Manor Farm Swallet at Charterhouse (Farrant, 1995). The connection between Long Hole and Gough's Cave is much more recent and due to chance interception by later passages. The second phase is represented by the high-level chambers in Gough's Cave, perhaps fed by a phreatic lift along Damocles' Rift. It may correlate with the lower levels in Longwood Swallet and Manor Farm Swallet (Farrant, 1995), and the main resurgence at the time may have been Cooper's Hole, now largely truncated by incision of the gorge. Gough's Old Cave may represent a late diversion of this phase or else a southerly derived inlet. The modern tourist route in Gough's Cave, and the isolated fragment of Cox's Cave further to the west, were formed in the third phase of phreatic cave development, possibly fed by a phreatic lift at Boulder Chamber, since bypassed by a lower connection. The abandoned passages are all phreatic with little vadose modification, and the fourth phase is the modern river passage still largely within the phreas. The four levels represent phases of adjustment to successive resurgences (Figure 5.10), whose positions were determined by surface lowering of the lowlands to the south of the Mendip Hills. Incision of the gorge may also have exerted a significant influence through breaching of phreatic drainage routes. The vadose entrenchment at the crests of the phreatic loops in the active river passage, particularly at Bishop's Palace, also reflects the lowering of the modern resurgence level.

Reservoir Hole is a complex system showing very strong control by faulting and associated fractures. The main passage has an inclined profile and appears to represent the downdip sector of an old phreatic loop on a tributary to the main Cheddar cave system.

Speleothems and thick clastic sediment deposits in the various cave levels of Cheddar Gorge may enable a chronology to be constructed for the sequence of events in the development of the cave system. Since this sequence reflects the history of the surface landscape through the Pleistocene, such an investigation will have a fundamental bearing on any future study of the geomorphological evolution of this area of Somerset.

Conclusion

The Cheddar caves clearly show phreatic cave development at the resurgence end of a major cave system extending through the dipping limestones of the Mendip Hills. Both active and abandoned passages exist, formed both along the strike, and with a dip-orientated, joint-guided, looping profile. The several levels of old cave record the Pleistocene entrenchment of Cheddar Gorge and the adjacent lowlands; they contain stalagmite which provides an absolute chronology, based largely on uranium-series dates. The relative simplicity of the dip-orientated section of the river passage, apparently lacking any tributaries or distributaries, contrasts with the converging passages in an analogous position behind Wookey Hole.

PRIDDY CAVES

Highlights

The Priddy caves represent excellent examples of predominantly phreatic swallet cave systems which have been rejuvenated, or abandoned, as a result of base-level lowering. The three main caves show evidence for significant differences in the duration of the initial phreatic phase and their ensuing vadose histories, despite all draining to the same resurgence. They provide a striking contrast with the dominantly vadose swallet caves of the Charterhouse area.

Introduction

The caves lie under the limestone plateau on the south and south-west slopes of North Hill, around the village of Priddy (Figure 5.1). Swildon's Hole, St Cuthbert's Swallet, Eastwater Cavern and Hunter's Hole are all major influent cave systems, though the latter two are now largely abandoned. Allogenic streams flowing from the Old Red Sandstone outcrop of the North Hill pericline cross the Lower Limestone Shales to sink near the base of the Black Rock Limestone, which dips south at 20–40°. All of the water draining through these caves resurges at Wookey Hole (Figure 5.1). The cave systems are formed mostly downdip and their accessible portions are developed largely within the Black Rock Limestone, locally about 280 m thick. The limestone in this area is broken by two important faults and several minor ones. The Priddy Fault runs roughly east–west across the northern part of the site, passing through the middle of the Swildon's Hole system where a brecciated zone up to 8 m wide is developed. Towards the eastern side of the site a smaller NNE–SSW fault lies very close to the Eastwater Cavern system.

The caves around Priddy have been intensively studied. Various aspects of cave geomorphology have been discussed by Drew (1975b), Ford (1963, 1965a, 1968), Newson (1969) and Irwin (1991). The hydrology has been discussed by Atkinson (1968b), Atkinson *et al.*, (1967), Drew (1975a) and Stenner (1968, 1978). Descriptions of the caves are given in Barrington and Stanton (1977), Irwin and Jarratt (1992) and Irwin (1991).

Description

Swildon's Hole is the most extensive of the caves at Priddy, and the streamway passes directly beneath the village (Figure 5.1). It has 9100 m of mapped passages, forming a complex dendritic system with many crossing links provided by high-level galleries (Figure 5.12). The main streamway takes a course westwards from the entrance to beyond Sump 1, and then turns south along the western margin of the system. Both legs of the streamway are oblique to the south-west dip. The first portion of the cave, as far as Sump 1, descends fairly steeply in a large vadose canyon (Figure 5.13). One section near the entrance was formerly filled almost entirely with clastic sediment, creating the 40 Foot Pot, but this was scoured out by the catastrophic floods of July 1968 (Hanwell and Newson, 1970). Deep rounded potholes, excavated by both solutional and mechanical action, are a notable feature of the steeper sections (Ford 1965a). Beyond Sump 1 the gradient of the cave is much lower (Figure 5.15), and the stream meanders over a floor of clastic sediment fill in a vadose canyon entrenched in the floor of a phreatic passage.

Along the course of the Swildon's streamway there are 12 flooded sections of passage where phreatic loops have been created by the obliquely downdip and up-joint route of the stream. Isolated sections of vadose canyon along the streamway, and elsewhere in the system, have formed by entrenchment through the crests of these phreatic loops, while the troughs have been infilled by clastic sediment, their ceilings migrating upwards by paragenesis. Sump 12, the present limit of explo-

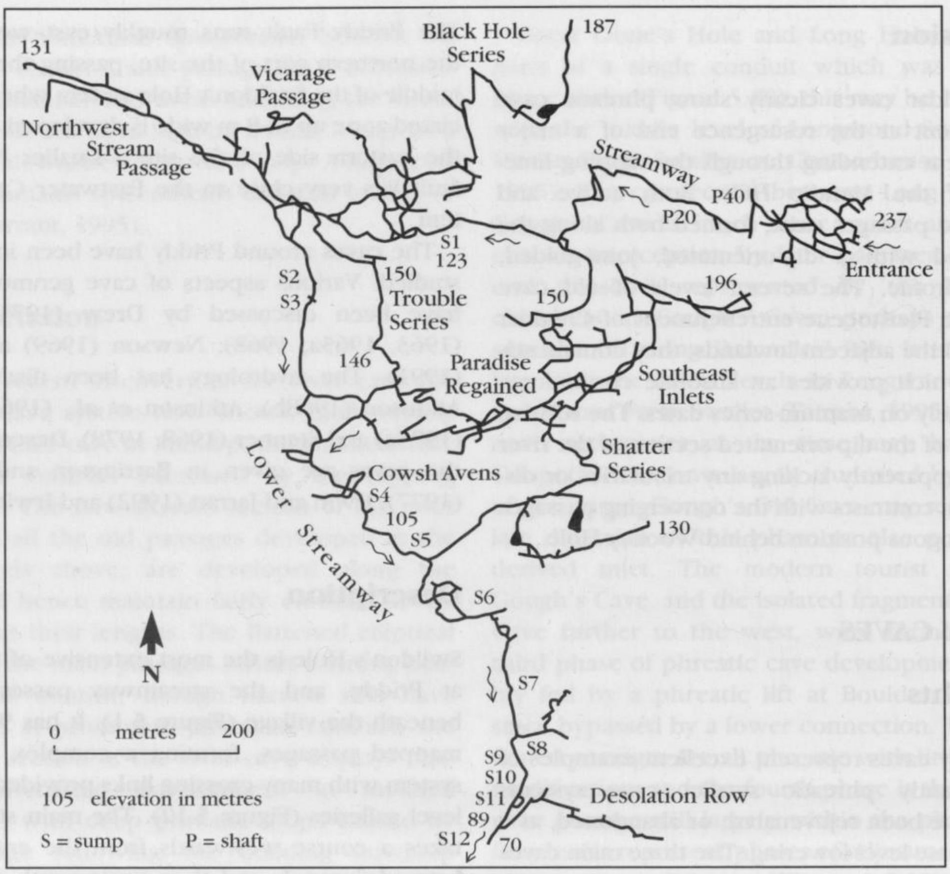

Figure 5.12 Outline map of Swildon's Hole (from survey by Wessex Cave Club).

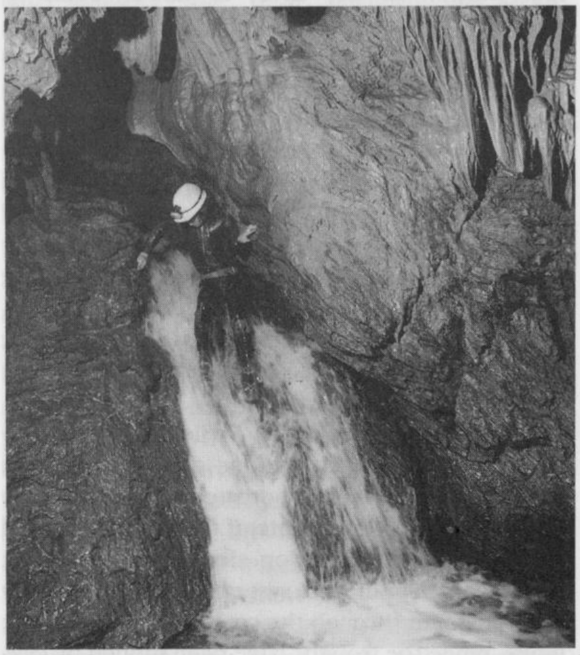

Figure 5.13 The cascading streamway in thinly bedded Black Rock Limestone in Swildon's Hole. (Photo: J.R. Wooldridge.)

ration, has been dived to a depth of 20 m, 167 m below the entrance. North of the upper limb of the main streamway lie the old rejuvenated inlets of Vicarage Passage and Black Hole Series, while in the area enclosed by the two limbs of the main streamway lies a complex series of abandoned passages at several levels. Some sections are blocked by collapse, but elsewhere they contain extensive clastic sediment deposits and are locally well decorated with speleothems. The Priddy Fault cuts across the cave, and Cowsh Avens (from Priddy Green Sink), Shatter Series and Southeast Inlets developed in its fracture zone.

St Cuthbert's Swallet lies east of Priddy (Figure 5.1), and is the most complex system on Mendip. It contains 7100 m of mapped passages, largely developed over a minor anticline plunging SSE (Figure 5.14). From the entrance, the streamway descends steeply for more than 100 m, beneath a multi-level series of inclined bedding-plane mazes of abandoned phreatic passages and chambers (Irwin, 1991). A roughly linear series of chambers and passages defines the south-western margin of the main part of the system and is developed along a minor fault, the Gour–Lake Fault (Figure

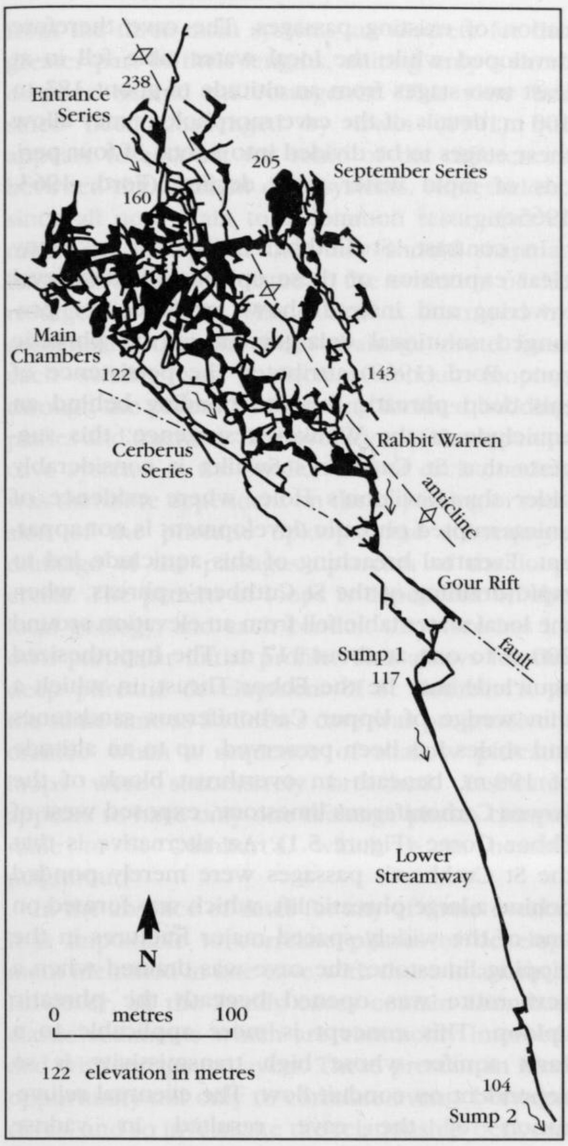

Figure 5.14 Outline map of St Cuthbert's Swallet (from survey by Bristol Exploration Club).

5.14). Caves cross this fault in at least two places. At the eastern crossing, the streamway continues as a gently sloping passage to Sump 1, which is perched. Beyond lies a further 300 m of tall, joint-guided, vadose canyon, partly entrenched beneath a gently ascending phreatic tube, leading to Sump 2. The abandoned phreatic passages and chambers have been extensively modified by collapse. They also contain abundant clastic sediment deposits and exceptionally fine speleothems of many types; these include some notable calcite curtains formed on the overhanging walls and some clusters of cave pearls in shallow pools beneath high shafts. Within one sediment sequence at least nine successive cycles of clastic sedimentation, vadose erosion and stalagmite deposition have been recognized.

Eastwater Cavern lies 400 m west of St Cuthbert's, and contains nearly 2500 m of explored passages reaching to a depth of 180 m. The upper part of the cave is mainly a steeply inclined phreatic maze formed on a bedding plane; there is only minor vadose trenching, as the cave has a very small catchment in its modern phase of development. Series of vertical vadose shafts, developed on fractures associated with the nearby fault, drop to lower levels with short sections of streamways; most passages end in small choked rifts. The cave system is largely abandoned but lacks significant speleothem development.

Hunter's Hole lies 600 m south-east of St Cuthbert's, and contains less than 300 m of passage. It drains a closed depression and has no allogenic stream input from North Hill. A vadose shaft 20 m deep drops directly into a remnant of large phreatic passage descending steeply to the south-east but largely choked with sediment and collapse debris.

Interpretation

The caves of Priddy are classic examples of predominantly phreatic cave development in steeply dipping limestone (Ford 1965b, 1968). Hence they complement the largely vadose cave systems in the Charterhouse area. Swildon's Hole is a fine example of underground dendritic drainage and has been cited as the type example of a shallow phreatic, influent cave system. This contrasts with St Cuthbert's Swallet which is a deep phreatic influent system (Ford 1965b, 1968; Irwin, 1991). In both caves, phreatic loops have developed by the stream flowing downdip and then rising up joints or faults. This is most clearly seen in the alternation of open vadose passage with short flooded sections in the Swildon's Hole main streamway. Rejuvenation of the streamway has led to vadose entrenchment into the crests of the phreatic loops, while the troughs have acted as sediment traps and have become infilled. Hence, not all of the loops are as clearly defined as those in the active phreatic sections of Wookey Hole and Gough's Cave, Cheddar.

In St Cuthbert's Swallet only a single ancient phreatic loop has been identified, but this extends to a depth of more than 80 m along the dipping shale–limestone boundary before rising obliquely up a fault. The presence of a minor plunging anticline has had a strong influence on the initial development of the St Cuthbert's cave system. In the first phase of development, passages were formed along the western flank of this anticline but, as swallets opened further upstream, the water sank and flowed along and down the eastern flank of the anticline. Later these networks coalesced to become a single system. In both this cave and Eastwater Cavern, complex inclined phreatic mazes have developed on bedding planes. Joints are limited in extent and appear to have played a relatively minor role in cave inception in the Priddy area, other than in the rising component of phreatic loops. Faults have exerted a significant influence in the development of rifts and vadose shafts, particularly in Eastwater Cavern.

The complex sequence of passages in the three main systems clearly reflects a long and complex history which probably extends well back into the Pleistocene and must relate closely to the history of the resurgence at Wookey Hole. Drew (1975b) and Ford (1965c) have identified a sequence of events for cave development in this area on the basis of morphological criteria but no speleothem dates are yet available to test their tentative hypotheses. Hunter's Hole was a major depression drain early in the Pleistocene (Drew, 1975b; Smith, 1977), though how it relates to the three swallet caves is unclear.

In Swildon's Hole, Ford (1963, 1965c) identified three main stages of development which he interpreted as responses to successively lower water tables, which then remained static for some time before dropping rapidly to the next level. Although Drew (1975b) questions the concept of a single water table in a limestone aquifer, he does accept that Swildon's experienced at least two or three rest levels during its development. The oldest section of passage appears to be the Shatter Series (Figure 5.12), draining south-west along the fault from a sink 150 m south of the present entrance. With the lowering of base level, the stream sink moved close to its present position to enlarge the second phase of passages, with flow along St Paul's Series to be joined by water from the Black Hole Series, flowing along Trouble Series and Paradise Regained. Further lowering of base level produced the system as seen today by development of new streamway passages (the third phase), vadose modification, capture of strike drainage by dip tubes and rifts, and rejuvenation of existing passages. The cave therefore developed while the local water table fell in at least two stages from an altitude of about 183 to 100 m; details of the cave morphology may allow these stages to be divided into a total of four periods of rapid water table decline (Ford, 1963, 1965c).

In contrast, St Cuthbert's Swallet lacks any clear expression of these episodes of base-level lowering and instead shows evidence for prolonged solutional enlargement in the phreatic zone. Ford (1968) attributed the persistence of this deep phreatic loop to ponding behind an aquiclude at the Wookey resurgence; this suggests that St Cuthbert's Swallet is considerably older than Swildon's Hole, where evidence of uninterrupted phreatic development is not apparent. Eventual breaching of this aquiclude led to rapid draining of the St Cuthbert's phreas, when the local water table fell from an elevation around 200 m to one at about 117 m. The hypothesized aquiclude may be the Ebbor Thrust, in which a thin wedge of Upper Carboniferous sandstones and shales has been preserved, up to an altitude of 190 m, beneath an overthrust block of the Lower Carboniferous limestone, exposed west of Ebbor Gorge (Figure 5.1). An alternative is that the St Cuthbert's passages were merely ponded behind a large phreatic lift, which was formed on one of the widely spaced major fractures in the dipping limestone; the cave was drained when a new route was opened beneath the phreatic uploop. This concept is more applicable to a karst aquifer whose high transmissivity is so dependent on conduit flow. The eventual rejuvenation of the cave resulted in vadose entrenchment of the present streamway canyon through the phreatic network as well as forming some high-level inlet passages. At least nine episodes of vadose erosion, clastic sedimentation and stalagmite deposition have been identified (D.C. Ford, 1964).

In Eastwater Cavern there appears to have been only minor vadose trenching, following draining of the phreas. It appears that, unlike the other systems, lowering of base level caused the main routes to be abandoned in favour of swallets further up the valley. The drainage from these now flows largely beneath the explored passages of Eastwater Cavern.

The individual histories of each of these three systems appear to differ considerably. Hydrological investigations by Atkinson *et al.*, (1967) suggested that the paths of the streams from the three main systems are discrete for the greater part of their lengths, uniting only a short distance behind the resurgence. This view has since been challenged by Irwin (1991) but appears to account for some of the differences between the adjacent cave systems. Nonetheless, since all now drain to a common resurgence it might be anticipated that they should share at least some features related to the evolution of the resurgence system. This notion is destroyed by recognizing that the main drainage route from each swallet was a discrete conduit looping through the phreas by following inclined bedding planes and fractures. The evolution of the separate cave systems at the swallet end of each conduit was therefore dependent on the bypassing or incision of the phreatic uploops, and subsequent drainage of the passages upstream of the loop crests. The pattern of loops is dependent on the local geology, and each conduit therefore has its own particular initial profile. This allows for the deep phreatic development of St Cuthbert's, at the same time as Swildon's cave was progressively drained when a sequence of shallow phreatic loops were successively breached. Eastwater appears to have only one drainage phase, comparable to St Cuthbert's, which is its nearest neighbour.

In the absence of dates for any of these events, it is impossible to correlate phases of development identified in one cave with those in another. However, all the Priddy caves contain abundant clastic sediments which are commonly interbedded with stalagmite layers. These present an ideal opportunity not only to correlate events between caves, and so investigate the relationship between the development of different sinkhole systems and their common resurgence, but also to document the climatic history of the area through the Pleistocene.

Conclusion

The Priddy site contains a series of sinkhole caves which show varying degrees of development in ponded phreatic conditions within the steeply dipping limestones. They were subsequently rejuvenated in response to surface lowering on the Somerset Levels, and show contrasting styles of evolution into the vadose environment. Sediment deposits and speleothems within the cave provide an exceptionally valuable record of Pleistocene environmental changes, whose full elucidation awaits analysis of both the radioactive and stable isotopes within the calcite speleothems.

WOOKEY HOLE

Highlights

Wookey Hole is a large resurgence cave developed in a unique geological situation, passing from the Carboniferous limestone into the cemented scree of limestone debris represented by the Triassic Dolomitic Conglomerate. The upstream reaches of the cave system display classic examples of deep phreatic circulation in a dipping aquifer, with successive passage levels developed in response to downward migration of the resurgence.

Introduction

The cave of Wookey Hole, located just north of the village of Wookey Hole, is operated in part as a show cave. It is a major resurgence lying on the southern margin of the Mendip limestone plateau (Figure 5.1) with a mean flow only exceeded by that of the Chedder Rising. It is the outlet for allogenic water draining off the North Hill sandstone inlier into the swallet caves of Swildon's Hole and St Cuthbert's Swallet, as well as much of the remaining subterranean drainage derived from the southern flanks of North Hill and Pen Hill. The Ebbor Thrust extends north-west–south-east only a short distance south of the mouth of Wookey Hole and Ebbor Gorge, and has preserved a narrow slice of Upper Carboniferous sandstones and shales between two masses of limestone. West of the Ebbor Gorge this potential aquiclude extends to an altitude of up to 190 m but to the east, near Wookey Hole resurgence itself, it has been breached by a Triassic valley. The show cave is developed entirely within this ancient ravine which is filled up to 100 m of Dolomitic Conglomerate, a poorly sorted Triassic breccia of limestone fragments in a calcareous silt matrix. The upstream portion of the cave is developed largely in Carboniferous limestone which has a south-west dip of 10–15°. The Dolomitic Conglomerate is crudely bedded and is crossed by a number of fractures aligned north-west–south-east.

Wookey Hole has an extensive literature covering aspects of cave development (Drew 1975b;

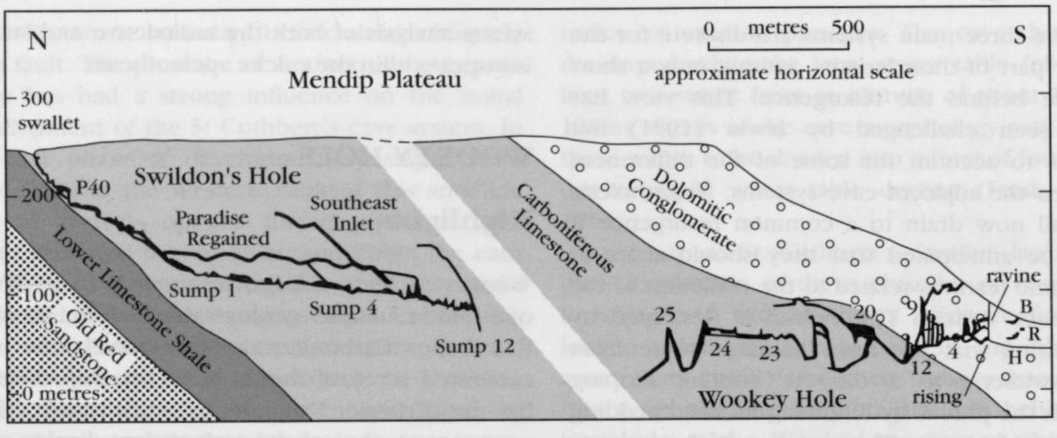

Figure 5.15 Semi-extended profile through the cave system from Swildon's Hole to Wookey Hole. The gap in the middle has not yet been reached by underground explorations; the distance between the explored limits of the two caves is about 2.3 km, and the vertical scale is exaggerated by five. The small caves in the ravine are keyed as: B = Badger Hole; R = Rhinoceros Hole; H = Hyaena Den (after drawings by W.I. Stanton).

Ford 1965b, 1968; Donovan 1988) and hydrology (Atkinson 1978; Atkinson *et al.*, 1967). Macfadyen (1970), Gatacre *et al.* (1980) and Duff *et al.* (1985) provide general accounts, and Barrington and Stanton (1977) and Irwin and Jarratt (1992) describe the cave passages.

Description

The present Wookey Hole resurgence is located near the base of the Dolomitic Conglomerate at the head of a short gorge, created by headward retreat of the cliff face over the active and abandoned cave exits. The lower part of the streamway, as far as Wookey 12, is developed entirely in Dolomitic Conglomerate (Figure 5.15). Largely flooded passages, typically 5 m across, link low bedding chambers and tall, narrow rift chambers developed along vertical fractures. From the roofs of some of these outer chambers, old outlet passages extend to the surface. Between the resurgence and Wookey 4 the modern streamway is almost level, but beyond this it descends in a major loop, emerging from the Carboniferous limestone at Wookey 12.

The inner streamway continues in a series of deep phreatic loops linking chambers which have been formed by vadose incision and modification of the loop crests. A larger section of vadose passage up to 15 m high, 6 m wide and more than 120 m long is developed at Wookey 23. The furthest point yet reached in Sump 25 is a gravel constriction 60 m below water level. Above the streamway at Wookey 20 an inclined rift, with many speleothems, ascends over a distance of 600 m to enter a boulder collapse at the junction of the Carboniferous limestone with the Dolomitic Conglomerate, beyond which the passage divides. One branch continues to ascend through the Dolomitic Conglomerate while the other re-enters the limestone before ending in a choke. An abandoned phreatic lift forms a truncated passage linking Wookey 9 to the hillside (Figure 5.15).

Three small cave remnants survive in the Dolomitic Conglomerate on the east side of the ravine below Wookey Hole cave. Badger Hole is the largest of these, with a 13 m wide entrance and almost 60 m of excavated passages. Close by lies the Hyaena Den containing some 45 m of passages. Rhinoceros Hole is another small fragment of phreatic passage 13 m long. All of these sites contain rich mammalian faunas, including Devensian mammoth, reindeer and hyaena, and Ipswichian rhinoceros and hippopotamus, together with Middle and Upper Palaeolithic human artefacts. These indicate that sediment deposition commenced at least 100 000 years ago (Donovan, 1988; Tratman *et al.*, 1971; Tratman, 1975).

Interpretation

Wookey Hole is the only large cave in Britain developed in both steeply dipping Carboniferous limestone and Triassic Dolomitic Conglomerate, a well-cemented fossil scree. The different influences which these two rock types have exerted on cave development is clearly seen in the contrasting passage morphologies between the outer part of the system, developed in Dolomitic Conglomerate, and the inner part developed in Carboniferous limestone. In the Dolomitic Conglomerate, the streamway flows through a series of shallow loops linking low, bedding plane chambers, or through tall, narrow rifts developed by solutional enlargement of vertical fractures under phreatic conditions. In the Carboniferous limestone, the cave forms phreatic loops over 60 m deep, with the stream flowing downdip along bedding planes, before rising through rifts on the joints. The cave represents the finest example in Britain of deep phreatic development in steeply dipping limestones, and also shows excellent examples of vadose incision through the loop crests.

Ford (1965b, 1968) considered that much of the phreatic character of the cave, and of the swallet caves at Priddy, developed through ponding behind a major aquiclude, perhaps of sandstone east of the Ebbor Thrust or of Triassic Mercia Mudstone, producing a considerable hydrostatic head. However, the Ebbor Thrust was already breached by Triassic times, while the resurgence stream would have rapidly incised into the soft Mercia Mudstone, preventing the development of a perched phreas for any length of time. The ascending rifts above Wookey 20 and 9 may represent feeders to relict vauclusian risings in the flank of the Mendip Hills. The high-level passages from the outer chambers may represent a series of distributary passages which developed, at successively lower levels, of approximately 80, 72 and 65 m down to the present water table at 60 m. These levels can be correlated with a sequence of altitudes and episodes of vadose incision on the crests of the phreatic loops. The successive lowering of the phreas overflow was controlled by the resurgence positions which developed in response to removal of the aquiclude confining the limestone to the south; ultimately this was a function of surface lowering of the plains to the south of the Mendip Hills during the Pleistocene (Macklin, 1985). The clastic and speleothem deposits within the cave offer the prospect of establishing an absolute chronology for this sequence of events, which can then be used in reconstructing the geomorphological evolution of the landscape in this area.

Conclusion

Wookey Hole is a major resurgence cave with the finest example of deep phreatic cave development in Britain. It is unique in being developed in both the Carboniferous Limestone and in the Triassic Dolomitic Conglomerate, and therefore demonstrates the different controls on karst drainage within these two important aquifers. The deep phreatic loops, controlled by the bedding and joints, include active and abandoned conduits in a configuration more complex than in the river cave at Cheddar.

BRIMBLE PIT AND CROSS SWALLET

Highlights

Brimble Pit and Cross Swallet are two of the finest closed drainage basins on Mendip, and together exhibit all the geomorphological features characteristic of Mendip closed basins. Both basins provide evidence of the periglacial development of lakes and overflow channels on the Mendip plateau during the last glaciation.

Introduction

A belt of twelve drainage basins extends along the southern rim of the Mendip plateau from Cheddar Gorge to Ebbor Gorge; they constitute a zone of polygonal karst (Figure 5.16). The Brimble Pit basin is one of the largest of the chain, while the adjacent Cross Swallet basin is smaller, but has a very distinctive internal morphology (Ford and Stanton, 1968). Both depressions once contained lakes which drained via a low col into associated overflow channels. The geomorphic significance of the closed basins was recognized by Ford and Stanton (1968), further elaborated on by Barrington and Stanton (1977), and briefly described by Duff *et al.* (1985).

Description

Brimble Pit is a pool at the lowest point of a shallow depression 10 m deep, over 1000 m long and 500 m wide (Figure 5.16). The floor of the basin is covered in a thick layer of horizontally stratified loessic silty clay, pitted with small sinkholes, one

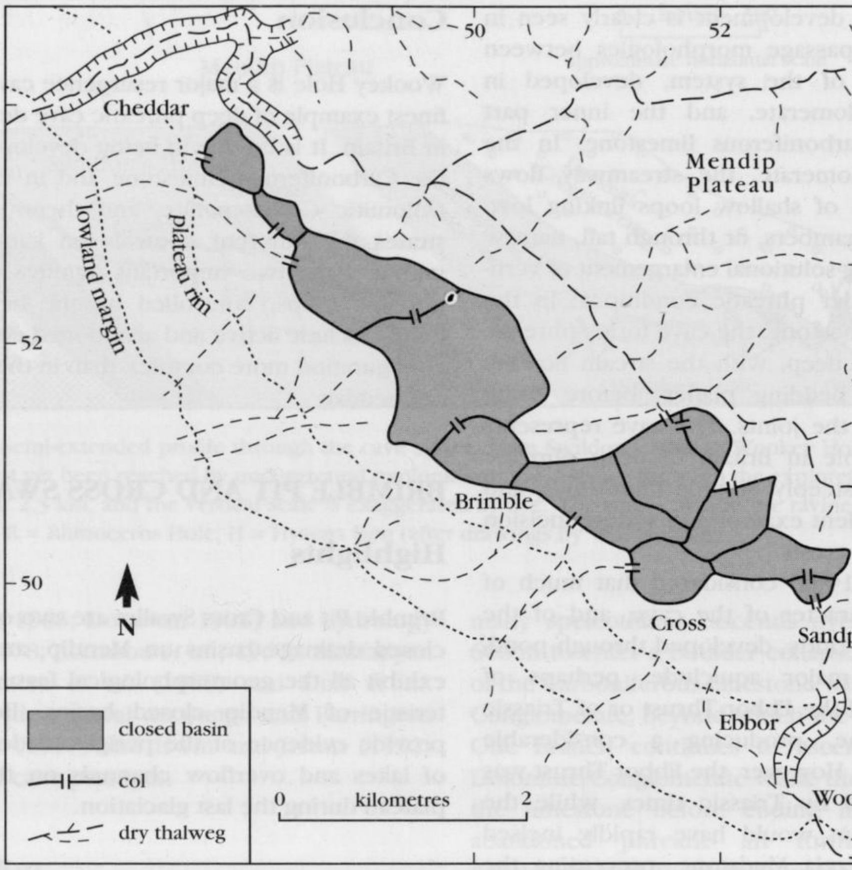

Figure 5.16 Topographic map of the group of closed depressions forming the zone of polygonal karst on the edge of the Mendip Plateau (after Ford and Stanton, 1968).

of which contains Brimble Pit. The pool is artificial; it originated as a sinkhole whose sides were puddled with silty clay to provide drinking water for cattle, and is now fed by road drainage. The basin is bounded by very gently graded slopes, dividing it from neighbouring depressions and valleys. The south-eastern margin of the basin is marked by a low col which feeds into an overflow channel incised several metres into the flanks of the plateau. Brimble Pit Swallet is a cave excavated to a depth of 20 m beneath one of the sinkholes in the basin; it is developed along the line of a major fault zone occupied by vein calcite, and is infilled with Triassic and Jurassic neptunian dyke sediments. Water draining into this swallet from an adjacent reservoir has been traced to Rodney Stoke rising. Locke's Hole is another excavated sinkhole, which yielded siliceous gravels similar to those seen in the Westbury Quarry deposits a few hundred metres to the south.

The Cross Swallet basin is similar in depth, but is only 500 m in diameter (Figure 5.16). It also has a marginal col and overflow channel, but not as well defined as that at Brimble Pit. A clearly defined corrosion terrace has formed at the level of the col, and extends all the way around the basin, locally extending to 23 m in width. At one point, an undercut limestone bluff rises above it. The main basin floor is formed on an infill of horizontally laminated yellow-brown silty clay at a level 5 m below the edge of the terrace. The clays are over 7 m thick, and within them a closed depression is cut 8 m deep at the centre of the basin. Fissures in the limestone floor of this have been penetrated for about 10 m depth before they become impassably narrow (Figure 5.17).

Interpretation

Ford and Stanton (1968) argued that the basins were initially formed by solutional activity during warm phases of the Pleistocene, and the sinks were blocked by permafrost during the ensuing cold periods. Meltwater became ponded during the brief summers until it spilled over the cols to

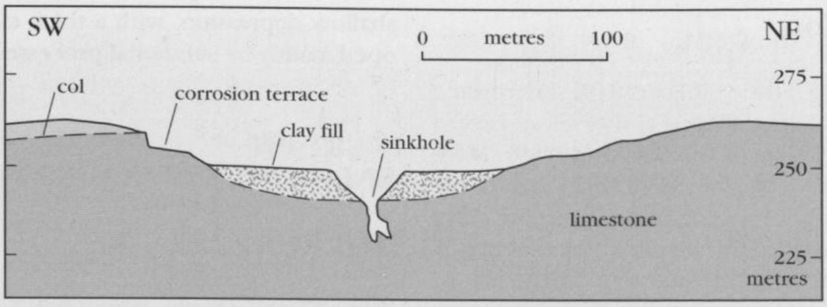

Figure 5.17 Cross-section through the depression and sinkhole of Cross Swallet (after Ford and Stanton, 1968).

cut the overflow channels. Hillwash, and perhaps windblown silt, formed the loessic silty clay deposited in the lakes, and helped seal the lake beds. In the Cross Swallet basin, the presence of the terrace indicates a stable lake surface at the col level. It is suggested that hydrostatic pressure was great enough to maintain slow talik leakage through the clay and the underlying permafrost into the limestone beneath.

The two basins combine to show all the features associated with Mendip closed depressions. These include cols leading to overflow channels, a terrace at col level etched into the limestone, old lake deposits forming flat thick clay floors, subsidence sinkholes developed in the clay fills, and impenetrable or choked caves developed below the sinkholes. Further work on the sedimentology and palynology of the loessic clay could provide important evidence on the palaeoenvironment in which the lakes were formed.

Conclusions

The site covers two of the finest major closed basins on Mendip, in an area of polygonal karst with no intervening valleys. Both basins show evidence of solutional excavation, followed by the periglacial development of lakes and overflow channels, and a return to underground drainage during interglacials.

SANDPIT HOLE AND BISHOP'S LOT

Highlights

Sandpit Hole and Bishop's Lot are two of Mendip's largest dolines. Sandpit Hole is a good example of a typical deep rocky doline, while Bishop's Lot is a broad, shallow, saucer-shaped doline.

Introduction

These two separate dolines are located about 4 km north of Wells and are developed on the flat surface of the Mendip plateau (Figure 5.1 and 5.15). They are of particular interest because they constitute two of the largest unfilled dolines on Mendip, and have distinctly contrasting morphologies. Both are developed on the Carboniferous Limestone and have been cited as evidence for the various theories which have been proposed for the formation of Mendip dolines (Stride, A.H. and Stride, R.D., 1949; Balchin and Coleman, 1959; Ford and Stanton, 1968), a resume of which is given by Smith (1975a). Both have been dug by cavers at some point, and the details of the digs at both sites are described in Barrington and Stanton (1977).

Description

Sandpit Hole is a large pit about 12 m deep and less than 50 m in diameter, with steep sides and a cliff face along one side containing several small caves. Sediment on its floor is a dolomite sand, which is largely a solutional residue left behind as a result of the weathering of granular dolomite. Below the floor, excavations by cavers show that limestone boulders continue to a depth of at least 16 m below the plateau surface. It is a fairly typical example of a Mendip doline, as yet unfilled.

Bishop's Lot is a large almost circular depression with a shallow saucer-shaped profile; it is 11 m deep and over 200 m in diameter. The margins are poorly defined and digging by Balch, around 1900, revealed a thick deposit of clay on its floor. Its morphology provides a clear contrast to that of Sandpit Hole.

Interpretation

Stride, A.H. and Stride, R.D. (1949) interpreted Sandpit Hole as being formed as a result of cavern collapse as did Coleman and Balchin (1959). More recently Ford and Stanton (1969) attributed the formation of dolines to gradual solution working down from the surface along joints, and deepened by the breakdown of the limestone at the top of the fissures. The origin of Sandpit Hole appears to be a combination of subaerial and under ground solution, undercutting and collapse of the limestone; the buried limestone boulders indicate the nature and scale of the collapse.

The nearby Whitepit closed depression, which is similar to Sandpit, has recently been excavated to reveal a cave at shallow depth. Directly below the surface depression, the cave passes through a debris pile at least 10 m across; the debris consists mainly of rounded limestone blocks, and appears to be derived largely from the rockhead zone of weathering. At Whitepit, it appears that an older open cave at a shallow depth has aided leakage of water into the limestone overlying the cave, accompanied by ravelling and partial collapse of the limestone to form the depression. It is possible that a similar mechanism can be invoked for Sandpit Hole, although more digging would be required to confirm this.

The evolution and deepening of the Bishop's Lot doline appears to have been dominated by solution rather than collapse. However, as almost nothing is known about the subsurface structure, the relative importance of subaerial solution and collapse cannot be estimated. It may represent an early form of the larger depressions, which include Brimble Pit and Cross Swallet, where premature leakage precluded any significant ponding and therefore prevented lateral expansion.

Conclusions

Two of the largest isolated dolines on Mendip have been formed by a combination of solution and collapse, and are typical of most of the depressions on the karst plateau. The two provide clearly contrasting morphologies, and represent opposite ends of the spectrum of processes and morphologies exhibited by the Mendip dolines. Sandpit is a steep-sided doline with rock walls and a floor of boulders continuing to depth, which may have been formed by collapse into an underlying cave. Bishop's Lot is a much broader, shallow depression, with a thick clay floor, developed mainly by solutional processes.

WURT PIT AND DEVIL'S PUNCH-BOWL

Highlights

Wurt Pit and Devil's Punch-Bowl are two of the most spectacular subsidence dolines in the Mendip Hills karst. They provide important evidence of the role of subsurface solution, and of leakage of water through impermeable cover rocks, in the formation of dolines on the Mendip plateau.

Introduction

These two dolines lie on the northern side of the Mendip Hills where the limestone plateau is only partly exhumed from its Mesozoic cover (Figure 5.1). Both Wurt Pit and Devil's Punch-Bowl are collapse dolines developed in the Jurassic Harptree Beds and the Triassic Mercia Mudstones, which overly the Carboniferous Limestone. In each case, rainwater is concentrated onto a series of seepage paths through the dominantly impermeable surficial rocks, into the limestone at depth, causing solution and collapse, and hence a depression. Their genesis is explained by Smith (1975a) and Barrington and Stanton (1977), and both sites are briefly described by Duff *et al.* (1985).

Description

Wurt Pit is a cup-shaped doline, 15 m deep and almost 100 m across, set in a gently sloping hillside with no associated valley features (Figure 5.18). It has a sharply defined rim and steep rocky sides. The surface rocks are the silicified limestones and mudstones of the Jurassic Harptree Beds, which are exposed on the walls of the doline. The Mercia Mudstones and Dolomitic Conglomerate are believed to underlie the site at no great depth, and they outcrop nearby. The nearest exposure of the Carboniferous Limestone is 500 m to the south-east; however, limestone is almost certainly present at depth directly beneath the doline.

Devil's Punch-Bowl is another impressive depression, over 50 m in diameter and almost

Figure 5.18 The Wurt Pit doline breaks the gently graded surface on the Harptree Beds outcrop. (Photo: A.C. Waltham.)

20 m deep. Like Wurt Pit, it is independent of the local drainage pattern, but it does have a small trench valley into it, and there is usually a small pool on its floor. Mercia Mudstones are exposed in the walls of the depression, and rotted siliceous material exposed in the trench may represent part of the Harptree beds. The Dolomitic Conglomerate and Carboniferous limestone appear in outcrops at distances of around 500 m north, west and south of the doline, and must underlie the site.

Interpretation

Wurt Pit is an excellent example of a subsidence doline developed in consolidated cover rocks. It was clearly formed by the solution of Carboniferous limestone at depth, followed by collapse and subsidence of the relatively impermeable and insoluble cover rocks (Smith, 1975a; Barrington and Stanton, 1977). The water responsible for the solution could have come from either or both of two sources; it may have been lateral flow entirely within the underlying limestone, but it was almost certainly joined by aggressive surface water leaking down through fissures in the Jurassic cover rocks. If lateral groundwater flow within the Carboniferous limestone was the dominant agent, then Wurt Pit may be more correctly described as a collapse doline.

Devil's Punch-Bowl has an origin which is broadly similar to that of Wurt Pit, except that the Mercia Mudstones in which it lies are almost completely impermeable. The ephemeral lake is a consequence of the very low surface permeability, and it drains only very slowly underground, where the morphology of any caves and fissures is unknown. Recent explorations have revealed cave systems beneath Wigmore (Jarratt, 1991; Hughes, 1991) and Attborough swallets, both of which are dolines comparable to the Devil's Punch-Bowl, located a few kilometres to the east. These have stream caves developed in the carbonates of the Carboniferous limestone and the Dolomitic Conglomerate, with active tributary passages and chambers formed wholly within the Mercia Mudstone. These mudstone caves appear to have developed as piping failures, enlarging progressively headwards, but the seepage flow which causes the piping erosion may have been initiated along calcareous horizons within the Mercia Mudstone. The same processes may be, or may have been, active beneath the Devil's Punch-Bowl doline.

Conclusions

The site covers two of Mendip's largest collapse dolines, and both are excellent examples of subsurface solution creating surface depressions, aided by leakage and piping through the surficial rocks, irrespective of surface morphology.

LAMB LEER CAVERN

Highlights

Lamb Leer Cavern is a fragment of a formerly phreatic cave system whose position, remote from the present catchments, is strikingly anomalous in the overall pattern of Mendip caves. It contains one of the largest chambers in Mendip and rare stratified aragonite flowstone. The area above the cave was the site for one of the earliest attempts to locate a cave by geophysical methods.

Introduction

Lamb Leer Cavern is located near the northern edge of the Mendip limestone plateau, 2 km south of Compton Martin (Figure 5.1). It is remote from any significant modern swallets and also from the anticlinal core of Old Red Sandstone, which provides most of the allogenic input to the present cave systems in Mendip, and lies more than 100 m above the adjacent lowlands. The cave is developed in fine-grained, chinastone facies of the upper part of the Clifton Down Limestone, dipping 15° east, and the east–west Lamb Leer Fault passes through it.

Little has been published on Lamb Leer. Descriptions of the passages are given by Barrington and Stanton (1977) and Irwin and Jarratt (1992), and its geomorphology is mentioned only briefly by Smith (1975a) and Stanton (1983).

Description

The cave is accessible through a mined shaft which intersects natural passage at a depth of 20 m. Downslope to the north, 100 m of passage passes through Beehive Chamber, with a 4 m high stalagmite boss at its centre, and continues beneath a 300 mm thick aragonitic flowstone floor to enter the east side of the Great Chamber, 20 m above its floor. The chamber is over 35 m high and 20 m in diameter. From it, a partly mined rift runs west for 60 m to the Cave of Falling Waters, where a small stream sinks in the floor and drains to Rickford Rising (Figure 5.2) (Barrington and Stanton, 1977). North from the chamber is St Valentine's Series, a complex of small phreatic tubes with some larger rifts and chambers, in places well decorated with speleothems. Extensive clastic sediment deposits and calcite and aragonite flowstones are preserved in several parts of the cave.

In 1938, L.S.Palmer undertook a resistivity survey of the area above Lamb Leer, one of the earliest attempts to locate caves by geophysical methods. He found an anomaly over the known cave and also a second anomaly suggesting another large cavity lies 130 m NNW off the Main Chamber (Barrington and Stanton, 1977). Palmer's Chamber, as it is known, remains unverified.

Interpretation

The position of Lamb Leer is anomalous among Mendip caves in its great distance from any present source of allogenic input. All of the cave passages are phreatic in origin, developed below their contemporary water table, yet the adjacent lowlands are now more than 100 m below the level of the cave. The Lamb Leer Fault may have influenced drainage routes and cave development. Large, isolated, phreatic chambers are known in various Mendip caves, but the Lamb Lear chamber is uncommonly large in relationship to its associated passages. The cave's distance from the main catchments on the Old Red Sandstone (Figure 5.1) suggests that it may represent the middle reaches of a system, formerly fed by sinks and vadose inlets much closer to the stratigraphic base of the limestone, whose upstream extension has been destroyed by surface lowering of the limestone plateau. The comparable middle reaches of the active Mendip caves of the Priddy–Wookey system (Figure 5.15) and the Charterhouse–Cheddar system remain inaccessible. Only the caves of the smaller St Dunstan's Well catchment can be explored over most of their length (Figure 5.20). Hence Lamb Leer may provide further information on this part of the anatomy of a Mendip karst drainage system.

Alternatively, Lamb Leer may have been fed by sinks developed on a formerly more extensive cover of Mesozoic rocks. Either scenario implies a considerable age for the system, perhaps extending back more than a million years to a time soon after the exhumation of the plateau from beneath the cover of Mesozoic strata. Investigation of the sediments and speleothems within the cave, including the aragonite flowstones, may confirm this, or at least establish a minimum age and sequence of development for the system. Such information would be extremely valuable in interpreting the geomorphological evolution of this area during the Pleistocene and earlier.

Conclusion

Lamb Leer Cavern is a fragment of an ancient phreatic system now isolated from present catchments as a result of surface lowering. It appears to be a relic from Tertiary drainage patterns, related to a higher plateau surface or a more extensive Mesozoic cover across the Carboniferous Limestone. The large, isolated chamber and the aragonite flowstone are two unusual features which make Lamb Leer so distinctive.

THRUPE LANE SWALLET

Highlights

Thrupe Lane Swallet is the most extensive vertical cave system in Mendip, containing the deepest vadose shaft in southern England. It provides a striking contrast to the more gently inclined passages of other Mendip caves which are controlled by bedding planes and joints, and it demonstrates the overriding major influence which faults may have on cave development.

Introduction

Thrupe Lane Swallet is a major stream sink for water draining south off the Beacon Hill inlier in the eastern Mendips (Figure 5.1). The Old Red Sandstone and Lower Limestone Shales are faulted against the Black Rock Limestone to the south by the east–west Thrupe Fault. The water resurges at St Andrews Well in Wells. Descriptions of the cave are found in Barrington and Stanton (1977), Irwin and Jarratt (1992), and Meade-King (1984), but there are no geomorphological studies to date.

Description

The cave contains just over 1400 m of passages, descending to a depth of 120 m (Figure 5.19). It is entered through an excavated shaft in one of a line of dolines which engulf two streams. All the sinking water is encountered again in the cave, where it follows a complex branching route through steeply descending rifts and inclined bedding plane passages. The cave system comprises a series of both active and abandoned, sub-parallel rifts trending close to north–south, containing vertical shafts up to 60 m deep and linked by smaller inclined passages; the lowest point is a choked rift.

Interpretation

Thrupe Lane Swallet has developed by vadose invasion and enlargement of a series of rifts previously opened by phreatic solution. It is atypical of Mendip caves due to its dominantly vertical development. The sub-parallel rifts and vertical shafts have been developed within the influence of major fractures associated with the Thrupe Fault. The bedding dips at 30° south-west, and smaller

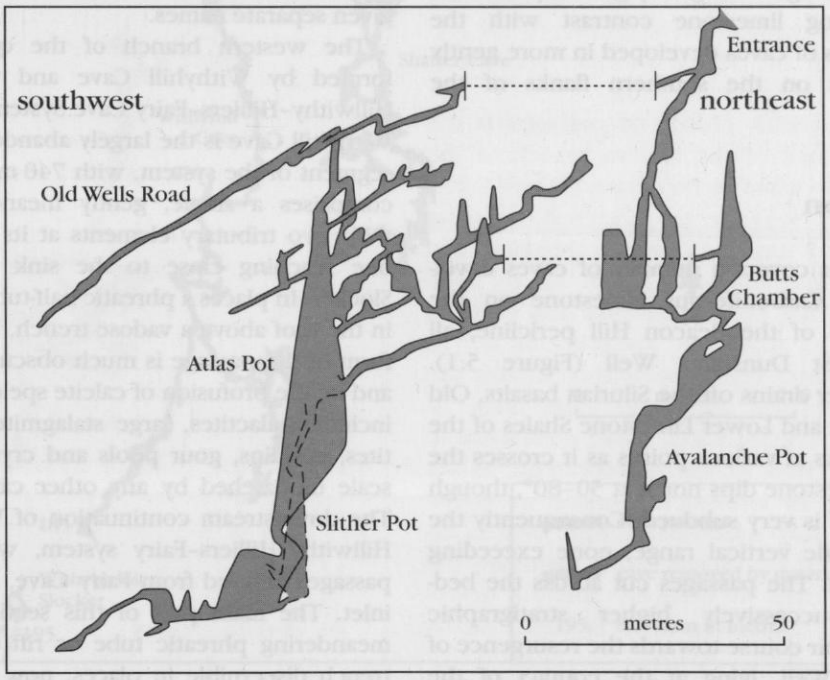

Figure 5.19 Projected profile through Thrupe Lane Swallet (from survey by Mendip Nature Research Committee).

downdip drains follow bedding-joint intersections to provide the links between the vertical rifts. At least six bedding planes have acted as inclined inception horizons, reflected in the pattern of cave development just updip of Atlas Pot (Figure 5.19). Only Reservoir Hole and Rhino Rift have comparable depth/length ratios in the Mendip karst, and Thrupe Lane Swallet is more akin to the vadose shaft systems in the Yorkshire Dales.

Conclusion

The cave is a complex vertical system of shafts and rifts developed in dipping limestone adjacent to a fault. Its vadose shafts demonstrate an unusual aspect of cave development in the dipping limestones of the Mendip Hills.

ST DUNSTAN'S WELL CATCHMENT CAVES

Highlights

The caves of the St Dunstan's Well catchment contain the most abundant, and best preserved, calcite deposits in the Mendip karst. They represent the only significant cave systems in Mendip which can be explored in almost their entirety from sink to rising. Their gently graded profiles in steeply dipping limestone contrast with the looped profiles of caves developed in more gently dipping strata on the southern flanks of the Mendips.

Introduction

The catchment covers a number of caves developed in the Carboniferous Limestone on the northern limb of the Beacon Hill pericline, all draining to St Dunstan's Well (Figure 5.1). Allogenic water drains off the Silurian basalts, Old Red Sandstone and Lower Limestone Shales of the inlier, and sinks at various points as it crosses the karst. The limestone dips north at 50–80°, though the local relief is very subdued. Consequently the caves have little vertical range, none exceeding 50 m in depth. The passages cut across the bedding into successively higher stratigraphic horizons in their course towards the resurgence of St Dunstan's Well, lying at the contact of the Carboniferous limestone with the overlying Namurian Quartzitic Sandstone. The Withybrook Fault passes through the Fairy Cave Quarry area, aligned NNW and dipping 50° west, with a small downthrow to the west; the fault has a brecciated zone, 15–20 m wide, with calcite and ferromanganese mineralization.

The cave systems of the western part of the catchment, in and around Fairy Cave Quarry, were comprehensively described by Price (1977, 1983). Passage descriptions of all of the caves are in Barrington and Stanton (1977) and Irwin and Jarratt (1992). The hydrology and water chemistry were investigated in some detail by Drew (1968, 1970), with further brief comments by Atkinson *et al.* (1973), Drew (1974) and Edwards (1994). Various aspects of the caves and their hydrology have been described and discussed in Smith (1975a).

Description

The western part of the site is centred around the now disused Fairy Cave Quarry which, during its working life, intersected the passages of two major connected cave systems (Figure 5.20) and provided the only known entrances to the caves. More than 4500 m of passages have been recorded, but 800 m of this has since been destroyed by quarrying. The remaining cave fragments opening in the quarry faces have been given separate names.

The western branch of the quarry caves is formed by Withyhill Cave and the connected Hillwithy–Hilliers–Fairy Cave System (Figure 5.20). Withyhill Cave is the largely abandoned, upstream segment of the system, with 740 m of passages. It comprises a single, gently meandering passage with two tributary elements at its upstream end, one reaching close to the sink at Withybrook Slocker. In places a phreatic half-tube is discernible in the roof above a vadose trench, but the original form of the passage is much obscured by collapse and by the profusion of calcite speleothems. These include stalactites, large stalagmite bosses, helictites, curtains, gour pools and crystal pools on a scale unmatched by any other cave on Mendip. The downstream continuation of Withyhill is the Hillwithy–Hilliers–Fairy system, with 1200 m of passages entered from Fairy Cave, an old phreatic inlet. The main part of this section is a simple meandering phreatic tube or rift, with a vadose trench discernible in places, now occupied by a misfit stream; there are a few collapse chambers.

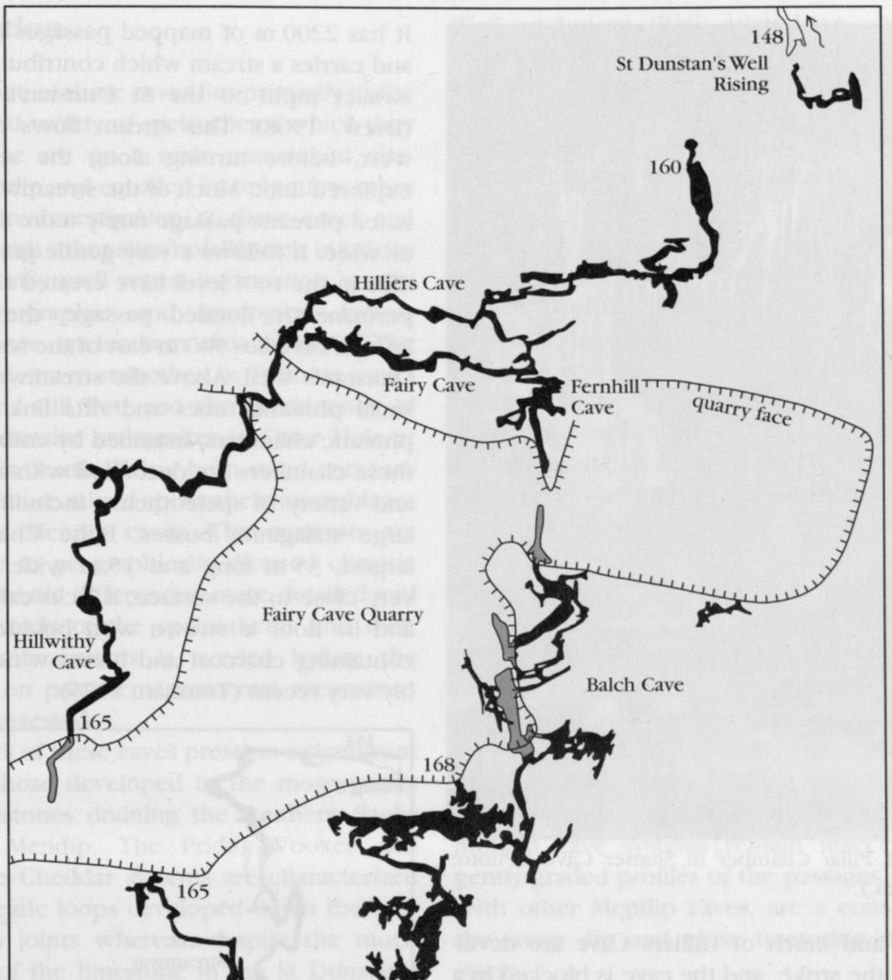

Figure 5.20 Outline map of the cave systems revealed where the Fairy Cave Quarry cut into the limestone outcrop (from survey by Cerberus Caving Club).

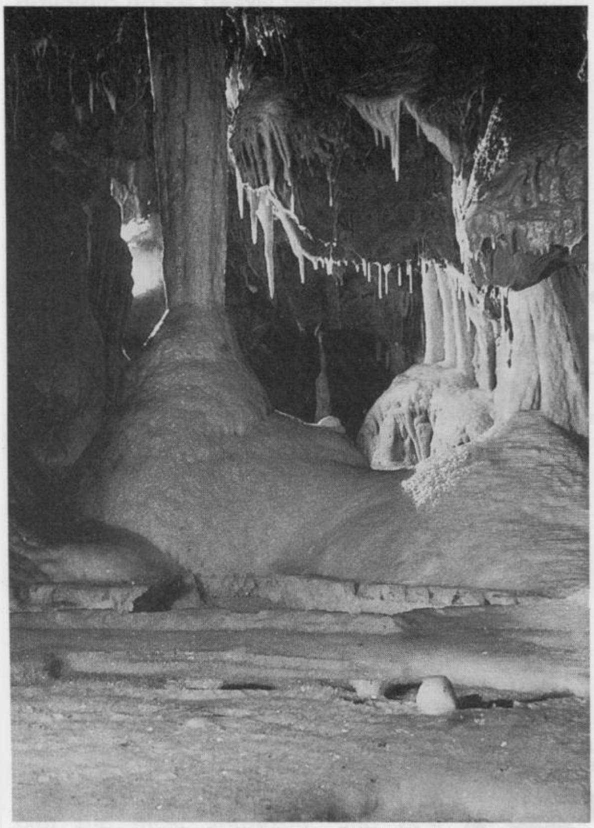

Figure 5.21 Pillar Chamber in Shatter Cave. (Photo: A.C. Waltham.)

Fairy Cave and much of Hilliers Cave are developed along the strike, and the cave is blocked in a well decorated chamber choked close to the surface, possibly at the site of a former resurgence only 70 m from the present risings.

Shatter Cave, with 1200 m of passages, is the upstream segment of the eastern branch of the main system breached by the quarry (Figure 5.20). It is mainly developed in the fractured limestone adjacent to the Withybrook Fault, and consists of a series of collapse chambers, each up to 20 m across, connected by smaller rifts and bedding plane passages. Abundant speleothems of all types, with notable crystal pools and curtains, are only marginally less impressive than those in Withyhill Cave (Figure 5.21). There is evidence of at least two phases of calcite deposition, as yet undated, with an interval of erosion or disturbance when many speleothems were broken up and re-cemented by later growth. Upstream the passage is blocked by collapse; and the downstream continuation has been largely destroyed by quarrying.

Stoke Lane Slocker is an important swallet cave in the eastern part of the catchment (Figure 5.1). It has 2200 m of mapped passages (Figure 5.22), and carries a stream which contributes 75% of the swallet input to the St Dunstan's Well risings (Drew, 1968). This stream flows to the north-west, before turning along the strike near its explored limit. Much of the streamway is a rejuvenated phreatic passage rarely more than 1 m high or wide. It follows a very gentle gradient, so that dips in the roof level have created six sections of permanently flooded passage; the end of the known cave lies 900 m east of the resurgence at St Dunstan's Well. Above the streamway, a series of small phreatic tubes and rifts link to high-level phreatic chambers, modified by collapse. Some of these chambers are decorated with an abundance and variety of speleothems, including some very large stalagmite bosses. Bone Chamber is the largest, 35 m long and 15 m wide, approaching very close to the surface; it lacks calcite deposits, and its floor is strewn with boulders and mud, containing charcoal and bones which are probably very recent (Tratman, 1975).

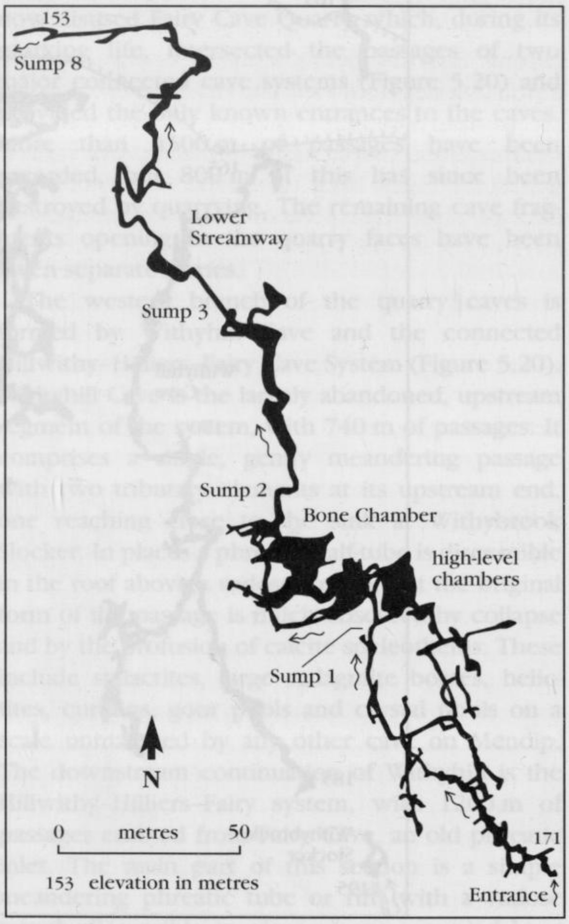

Figure 5.22 Outline map of Stoke Lane Slocker (from surveys by Wessex Cave Club and Cave Diving Group).

Interpretation

The importance of these caves lies primarily in the abundance and variety of speleothems which they contain. These are on a scale unmatched elsewhere in Mendip and equalled by only a few other sites in Britain. Investigation of these caves and comparison with other sites notably rich in calcite speleothems may well reveal information on the climatic, topographic and geological factors which influence speleothem development. The dominance of straw stalactites in Pennine caves such as Strans Gill Pot, and the prominence of much more massive stalagmites in Otter Hole at low altitude in South Wales, both stand comparison with the more mixed speleothem assemblages in these East Mendip caves. The contrasts are probably due to geographically dictated climatic and palaeoclimatic differences; more detailed and quantitative study of the speleothems and their geological environments is needed before the implications on palaeoenvironmental reconstructions can be assessed.

The profiles of these caves presents a significant contrast to those developed in the more gently dipping limestones draining the southern flanks of western Mendip. The Priddy-Wookey and Charterhouse-Cheddar systems are characterized by large phreatic loops developed down the bedding and up joints whereas, despite the much steeper dip of the limestone in the St Dunstan's Well catchment, these caves have gently graded profiles. The fracture density within the limestones has been high enough for the caves to develop on an almost graded profile, without deflection by the bedding planes into deep loops (Ford, 1971).

These caves of eastern Mendip show a sequence of development, from phreatic chambers, followed by phreatic conduits close to a graded profile, and then rejuvenation and modification by vadose erosion, with associated collapse and calcite deposition. This sequence reflects changes in karst drainage associated with landscape evolution through the Pleistocene; absolute dating of the calcite speleothems is required to recognize the time-scale involved.

Conclusion

The catchment contains the accessible fragments of three cave systems, all of which are notable for the exceptional profusion, variety and beauty of their calcite speleothems. The caves can be explored over almost their full length from sink to rising, whereas the middle reaches of most other Mendip cave systems remain inaccessible. The gently graded profiles of the passages, contrasting with other Mendip caves, are a consequence of the steep dip and close fracturing of the limestone.